State of California
California Regional Water Quality Control Board, Los Angeles Region

D R A F T J U L Y 3 1 2 0 0 9

Draft Technical Staff Report

Evidence in support of an Amendment to the *Water Quality Control Plan for the Coastal Watersheds of Los Angeles and Ventura Counties*

to Prohibit on On-site Wastewater Disposal Systems in the Malibu Civic Center Area

Technical Memorandum #3: *Pathogens in Wastewaters that are in Hydraulic Connection with Beaches are a Significant Source of Impairment for Water Contact Recreation*

By
Elizabeth Erickson,* Registered Geologist
Groundwater Permitting Unit

** The author would like to thank Regional Board staff, Joe Luera and interns Albert Chu, Shentong Lu, Shannon Liou, Justin Tang, Tessa Nielsen, Holly MacGillivray, Thomas Palmieri, Ryan Thatcher and Yifei Tong for their assistance in preparing map, tables and graphs.*

Technical Memorandum #3: ***Pathogens in Wastewaters that are in Hydraulic Connection with Beaches are a Significant Source of Impairment for Water Contact Recreation***

By
Elizabeth Erickson, Registered Geologist
Groundwater Permitting Unit

D R A F T

J U L Y 3 1 2 0 0 9

1. Purpose

The purpose of the study is (a) to measure the discharge of enterococcus, a fecal-indicator-bacteria for human pathogens, from septic systems (On-site Wastewater Disposal Systems or OWDS) in the Malibu Civic Center onto adjacent surface waters and beaches, and (b) to determine human health impacts of septic system wastewater disposal on beach users.

2. Study Design and Data

The study design is (a) to examine the distribution of bacteria in groundwater beneath the Malibu Civic Center area, (b) to use beach studies to determine likely fate and transport paths and (c) to use epidemiology studies to estimate health impacts.

Fecal-indicator-bacteria are identified in septic discharge, in leachfields/seepage pits, in groundwater, in streams and beaches and, through rainfall records and frequency distributions, related to groundwater discharge. On-site Wastewater Disposal System performance data from reporting permitted commercial facilities, groundwater monitoring data and beach monitoring data at the Malibu Civic Center are studied for the presence of enterococcus bacteria, which can originate in the human gut, have been used as indicators of human pathogens, and are the basis of a marine recreational criteria for the protection of human health.

The Los Angeles Regional Water Quality Control Board (Regional Board) was tasked with permitting about 40 commercial facilities in the study area after the year 2000 when the State Water Resource Control Board (SWRCB) eliminated waivers for septic systems. Twenty one permitted facilities were transferred to the City of Malibu for oversight under Memorandum of Understanding signed in 2004. Twenty permitted commercial facilities are under Regional Board's oversight. Notices of Violation (NOV) were issued in the spring of 2009 to 20 facilities for non-compliance with WDR and Time Schedule Orders including failure to submit monitoring reports. Of the permitted septic systems which provided monitoring information, four provided end-of-pipe measures and ten submitted groundwater monitoring results. End-of-pipe discharge reports from permitted systems describe effluent as it enters the leachfield/seepage pit. Enterococcus densities were also examined in groundwater monitoring wells surrounding the leachfields which receive septic system effluent.

The City of Malibu measures groundwater quality periodically throughout the Malibu Valley basin which receives the effluent from the septic systems in the Civic Center. The ground water monitoring of 20 wells in the Malibu Civic Center area was completed by the City of Malibu in 2004 and summarized by Stone Environmental, Inc. (Stone) in 2004, but water level and water quality monitoring information collected since that date has not been submitted to the Regional Board and is not included in this analysis.

State and local agencies and nonprofit organizations measure enterococcus in the surface waters and on the beaches adjacent to the Malibu Civic Center area and these records were examined. As an example, beach data was collected as part of the Coordinated Shoreline Monitoring Plan for Santa Monica Bay beaches and the result of a multi-jurisdictional collaborative effort, involving representatives from (a) municipalities and public agencies responsible for the implementation of the Santa Monica Bay Beaches Bacteria Total Maximum Daily Loads (TMDLs), (b) the Regional Board, and (c) the environmental advocacy groups. The "Santa Monica Bay Beaches Bacteria Total Maximum Daily Load Coordinated Site Monitoring Plan, April 7, 2004" (CSMP) went into effect on April 28, 2004 and can be found at http://ladpw.org/wmd/npdes/beachplan.cfm . All sampling procedures are standardized, including morning sampling in ankle-deep water at fixed points with testing in State certified laboratories.

The CSMP monitoring sites were selected to sample the wave wash of 55 miles of shoreline encircling Santa Monica Bay. The sites include major drains that have measurable flow to the beach at the wave wash during the wet weather and beaches that are used for wading and swimming. Each subwatershed was represented by at least one sampling site. Where a storm drain of freshwater outlet is absent, the midpoint of the beach is used. Based on observations of the Santa Monica Bay Restoration Commission staff and Regional Board staff, only the monitoring sites at Santa Monica Canyon and Ballona Creek have flow to the beach wave wash during dry weather throughout August, September, October and November of each sample year.

Among the beach monitoring information collected, the study focused on records for June through August in 2005, May through October in 2006, April through October in 2007, and May through October in 2008, on a total of 58 beaches, 36 of which receive freshwater drainage (with MS-4 stormwater permits) and 22 of which do not. The beaches stretch from El Pescador Beach in the northwest to Redondo Beach in the southeast. Winter data was not evaluated as septic discharge through groundwater to the beach is anticipated to be smaller in contrast to stormwater bacteria discharge to the beaches after rain events.

The sample sites were sorted according to characteristics, such as watershed size, land-use, fecal-indicator-bacteria concentrations, septic system presence, wave strength and beach visitor population. A full array of site characteristics were found to be represented: sewage or septic system waste treatments, adjacent groundwater levels of enterococcus levels above 1 MPN/100mL, watershed sizes ranging from 813 acres to 81,980 acres, urban acres ranging from 128 acres to 68,700 acres, and wave action identified from surf web-sites ranging from none to persistent. Some beaches had adjacent lagoons, tidally influenced pools, stormwater containments and low flow diversions.

Two epidemiology studies, one by the U.S. Environmental Protection Agency (EPA) used in the development of the existing marine recreational swimming criteria based on enterococcus densities, and a recent study from Wisconsin (Borchardt, 2003) correlating health impacts on children to septic system density, were used to estimate the human health effects of a septic system disposal for the Malibu Civic Center

Attachment 3-1 contains a discussion of the statistical analysis completed as part of this study. Attachment 3-2 contains an expanded reference list.

Groundwater Discharge

This study examines correlations between bacteria distributions in groundwater basin, surface waters and on many beaches with different characteristics. A different study design would be necessary to confirm causation. For the purposes of this study, groundwater discharge is defined as any flow which passes through the beach face or subsurface to enter the wave zone. It may be comprised of varying volumes of (a) stormwater or urban runoff which has entered the groundwater upgradient from the beach and discharges at the beach, (b) septic effluent which enters the groundwater as a discrete plume or with mixing and discharges at the beach, (c) groundwater which has resided for longer than a season in the aquifer and discharges at the beach. In every beach studied, except Ballona Creek and Santa Monica Canyon beaches, freshwater entering the wave zone must pass through the sand of the beach face during some of the summer months.

When septic beaches are compared with sewered beaches during dry weather, septic beaches may receive groundwater discharge of septic effluent, urban flows, and groundwater, while sewered beaches are limited to a mix of urban and groundwater flows.

Peer Review

A peer review of a portion of this work was conducted between June 8, 2009, and the public release of this document. An early technical review resulted in recommendations from the reviewers (a) to enhance the confidence of the conclusions using statistics, (b) to recommend additional studies to confirm and extend the results shown here, and (c) to emphasize the complexity of the subsurface hydraulic and microbiological environment between septic discharge and the ocean which have limited a simple characterization of a relationship between human illness from marine recreational swimming and coastal septic use. In response to these comments, additional statistical results were completed and the qualitative conclusions were made on human health risks. The external technical reviewers were Dr. Mark Gold (Heal the Bay), Mr. Steve Weisberg and Dr. John Griffith (Southern California Coastal Water Research Project or SCCWRP), Dr. Alexandria Boehm (Stanford University) and Dr. John Izbicki (US Geological Survey), all of whom have completed research on pathogens on beaches.

Dr. C.Y. Jeng (Department of Toxic Substances Control) provided helpful discussions on statistics.

Integration with Ongoing Studies

An epidemiology study of Surfrider Beach by SCCWRP is planned for the summer of 2009. Groundwater assessment is planned for a seven-day period in July 2009 by Dr. John Izbicki. While providing critical and important information, these two studies are limited in their ability to deny a causal relationship between septic systems and bacteria because (a) groundwater and epidemiology are not examined over an extended period of time and (b) groundwater identification of bacteria transport is repeatedly confounded by time, tide and effluent pathway dependent variations (Boehm et. al., 2004). Descriptions of the ongoing studies are available from the Regional Board.

3. Results

Bacteria in Groundwater

Enterococcus bacteria are found being discharged from OWDS, in the adjacent leachfields/seepage pits, throughout the groundwater basin, and in the subsurface adjacent to Malibu Creek, Lagoon and the Civic Center Beaches.

End-of-pipe bacteria measurements were reported for four permitted sites in the Malibu Civic Center. Half of the measures show enterococcus bacteria concentrations larger than or equal to total or fecal coliform measures[1]. The data show the typical wide variation in measures of water samples examined for this study.

All four reporting sites had disinfection so the end-of-pipe measures show events which are present during the failure of chlorine, ultraviolet or ozone treatment. Technical memorandum #1 quantifies the frequency of these failures as does the permit violations notices discussed above.

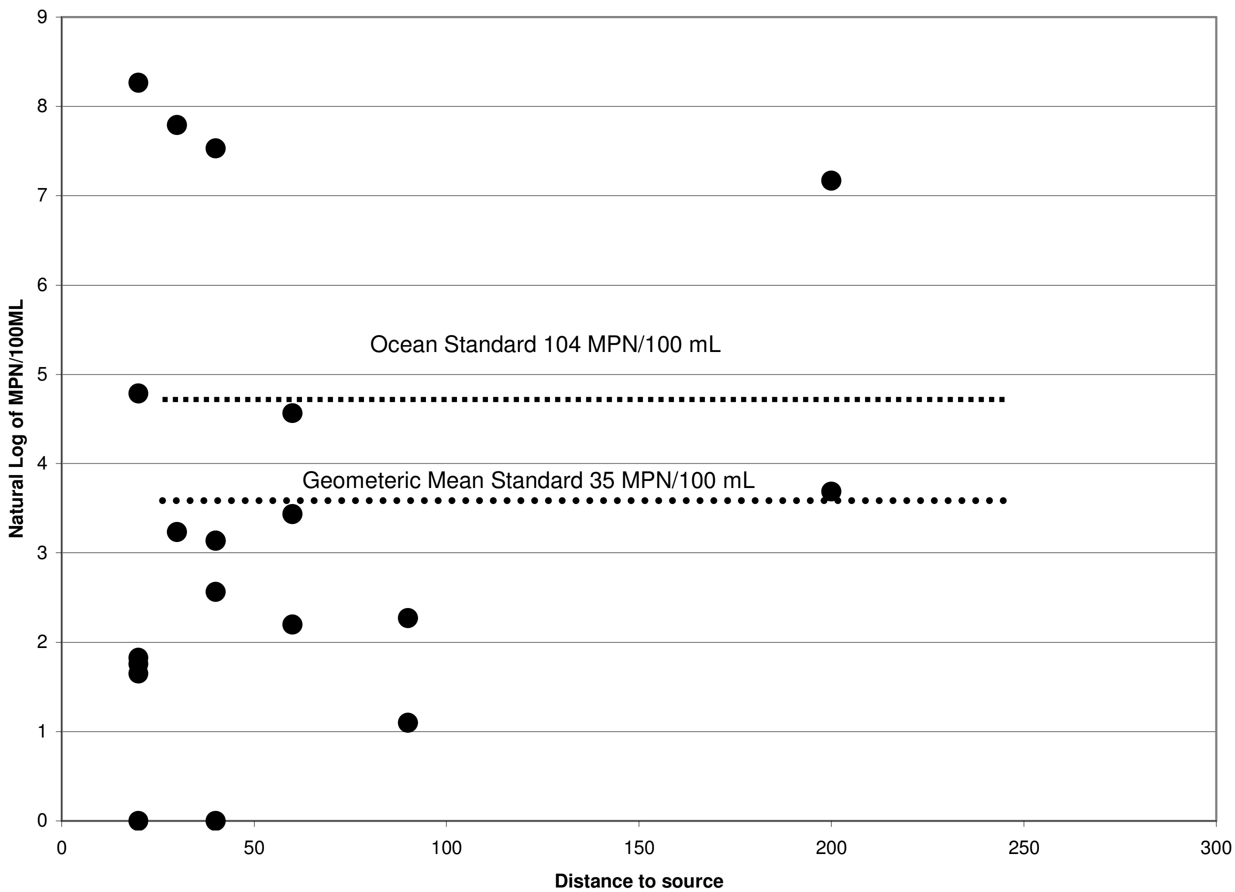
Table 1: End-of-Pipe Effluent Bacteria Densities MPN/100mL reported for permitted Malibu Civic Center Commercial Facilities <u>with Disinfection</u>. Highlighted measures are enterococcus values in human waste which exceed fecal and/or total bacteria counts or are above 35 Most Probable Number (MPN)/100 mL (geometric mean standard for beneficial use of body contract recreation (REC-1)).

Site	Total	Fecal	Enterococcus
Malibu Creek Preservation	1,600	350	46
	1,600	140	110
Malibu Beach Inn	Not measured	2	2
	Not measured	2	2
Malibu Colony Plaza	105	2	2
	4,000	2	2
	1,600	1,600	2,419
	1,600	1,600	2,419
Fire Station 88	1,600	1,600	2,419
	9,000	Not available	90,000
	24,000	24,000	24,000
	30,000	2,400	50,000
	240,000	Not available	240,000
	300,000	50,000	1,600,000

[1] All bacteria measures, even from the same waste stream, are highly variable. Enterococcus bacteria in end-of-pipe measures correlate with fecal ($R^2 = .88$) and total ($R^2=.84$) bacteria in those same samples.

An examination of maximum enterococcus densities in groundwater monitoring wells adjacent to nine permitted Advanced On-site Wastewater Disposal Systems in the Malibu Civic Center found that the groundwater bacteria densities are present at elevated levels and decrease from 10,000,000 MPN/mL to zero with distance from the subsurface discharge point to the monitoring well (Figure1).

Figure 1: Natural Log of Enterococcus in Groundwater Wells versus distance from the end-of-pipe in feet in the Malibu Civic Center (outliers at 200 feet distance are attributed to bacteria transport through fractures to the Malibu Administration Center, possibly from residential septic systems)



Elevated bacteria levels were found throughout the Malibu Valley groundwater basin which underlies the Malibu Civic Center area as reported in 2004 by Stone Environmental in “Final Report- Risk Assessment of Decentralized Wastewater Disposal Systems in High Priority Areas in the City of Malibu CA.”(Figures 2a, 2b and 3). Large densities are seen adjacent to the receiving waters. Fifteen out of 20 wells in Stone 2004 Study and 16 out of 27 permit monitoring wells contained maximum enterococcus exceeding water quality objective of 104 MPN/100ml for beneficial use of REC-1, i.e., 31 out 47 wells (76% wells) have exceedance.

Figure 2a: Chart of Maximum Enterococcus MPN/100 mL for 20 groundwater wells in the Civic Center area from Stone 2004 Study (well locations are shown in Figure 3).

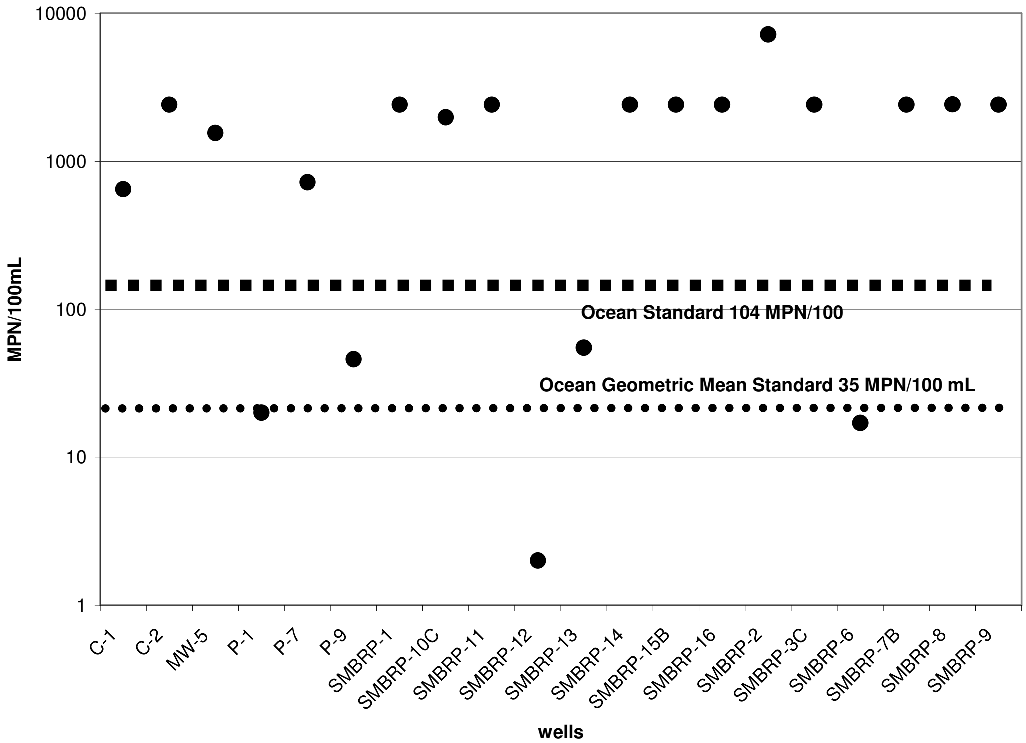
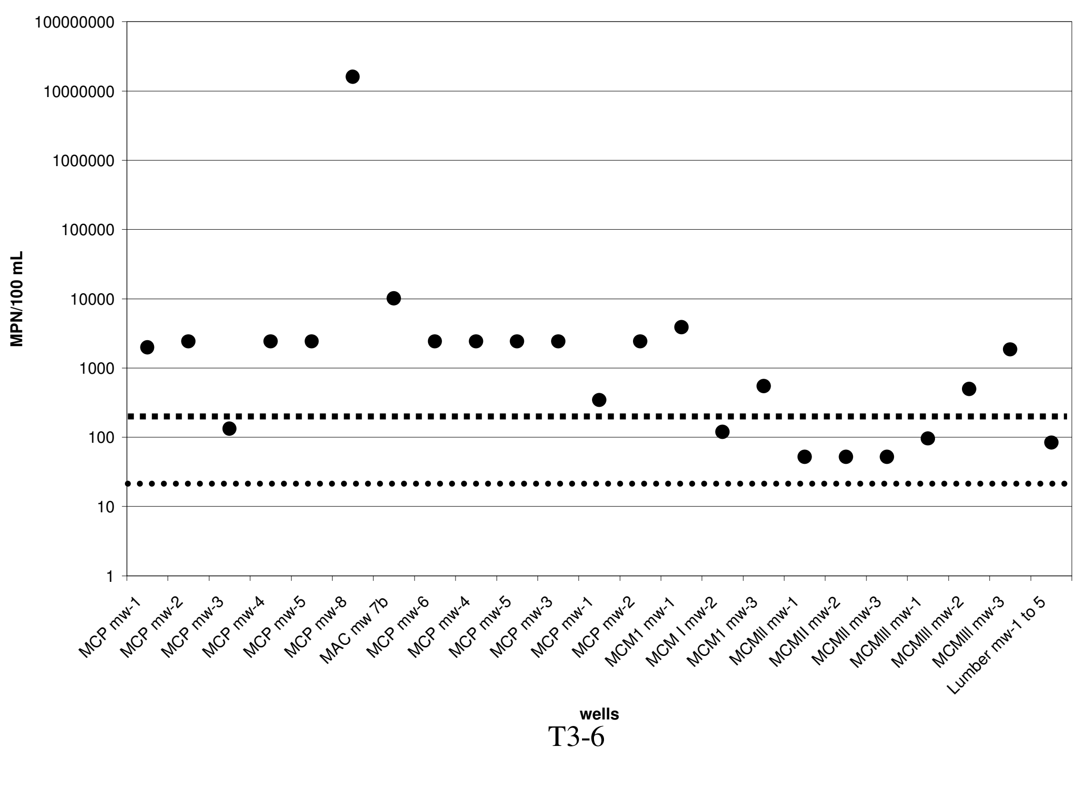
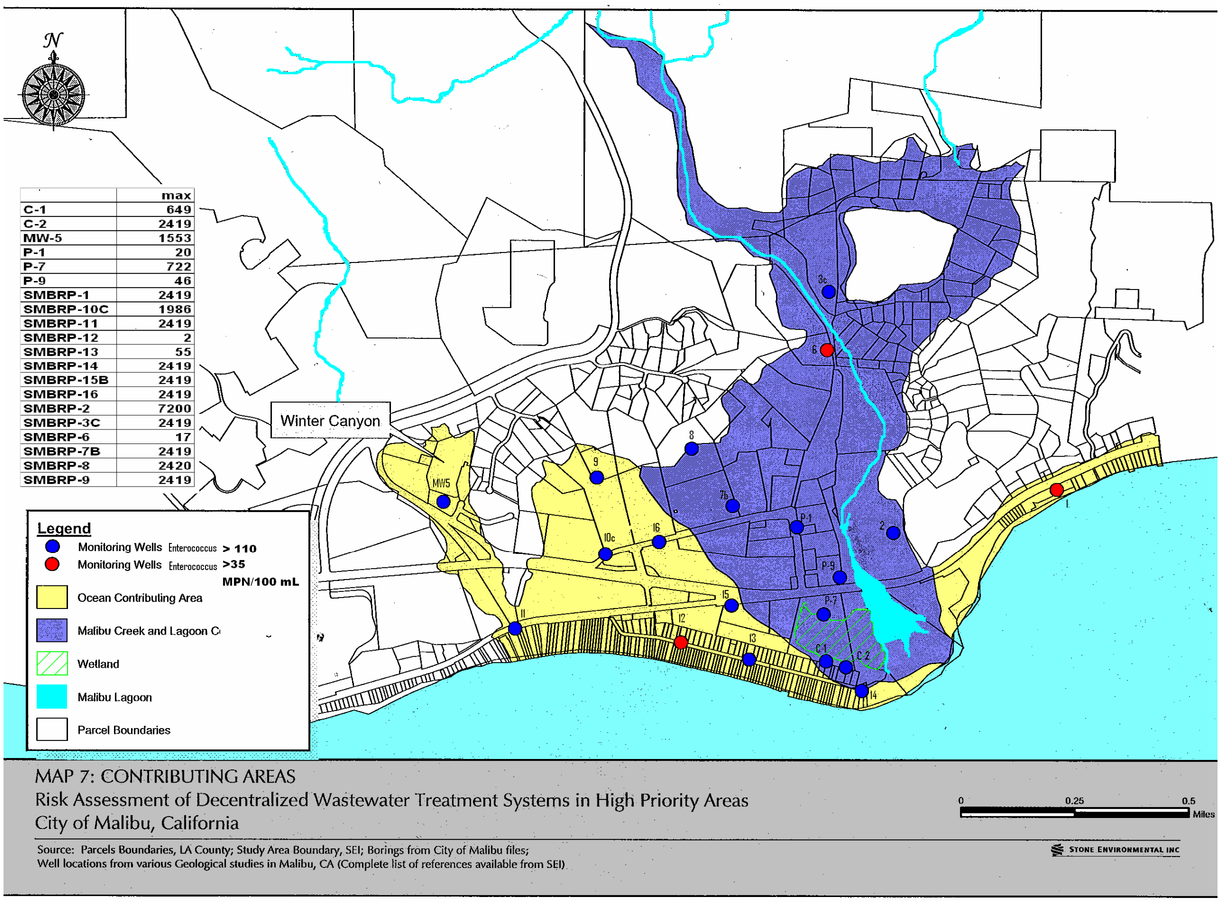


Figure 2b: Chart of Maximum Enterococcus MPN/100 mL for 27 permit monitoring wells in the Civic Center area (well locations are shown in Figure 1 of Technical memorandum #2).



DRAFT JULY 31 2009

Figure 3 after Stone 2004 shows the <u>maximum</u> enterococcus measures in wells in the Civic Center area. (Densities above 104 MPN/100 mL are the darkest spots).



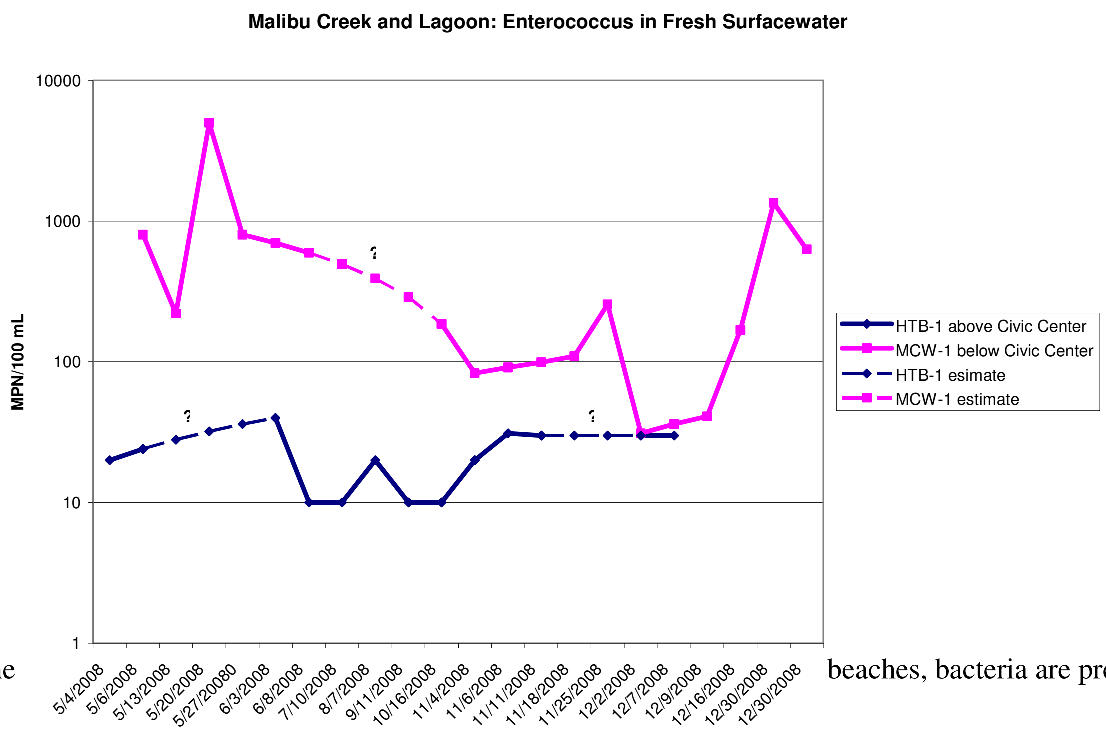
Bacteria in Surface Water

Summer levels of the fecal-indicator-bacteria enterococcus are not as high in the water entering Malibu Lagoon from the Malibu Creek watershed (see Figure 4), as they are downstream of the Malibu Civic Center area. The contrast can be seen in Figure 5 showing enterococcus at Lower Malibu Creek sampling station HTB-1 and Lagoon sampling station MCW-1. Some bacteria in surface water flows in the Malibu Civic Center may enter the surface water with summer groundwater discharge from the Malibu Civic Center area and result in higher enterococcus in the Lagoon. Further, the bacteria in the lagoon surface water must enter the groundwater beneath Surfrider Beach again before discharging into the wave zone at MC-2 as seen on the Figure 4 below.

Figure 4: Malibu Civic Center Surface water and Beach Sampling Points. (HTB-1 where surface water from Malibu Creek watershed enters the lagoon, MCW-1 where Malibu Creek enters Malibu Lagoon after receiving groundwater discharge from the Malibu Civic Center. Also see are beach sampling points MC-1 at the Beach adjacent to Malibu Colony, MC-2 at the breach point of Malibu Lagoon on Surfrider Beach, MC-3 at the beach adjacent to Malibu Pier and SMB-1-13 at Carbon Canyon Beach where Sweetwater Canyon discharges.)

The Malibu Creek and Lagoon TMDL also evaluated the bacteria levels in surface water and set loads for total bacteria which are less than the loads measured in 2004.

Figure 5: Enterococcus in Surface water at Malibu Civic Center



On the beaches, bacteria are present

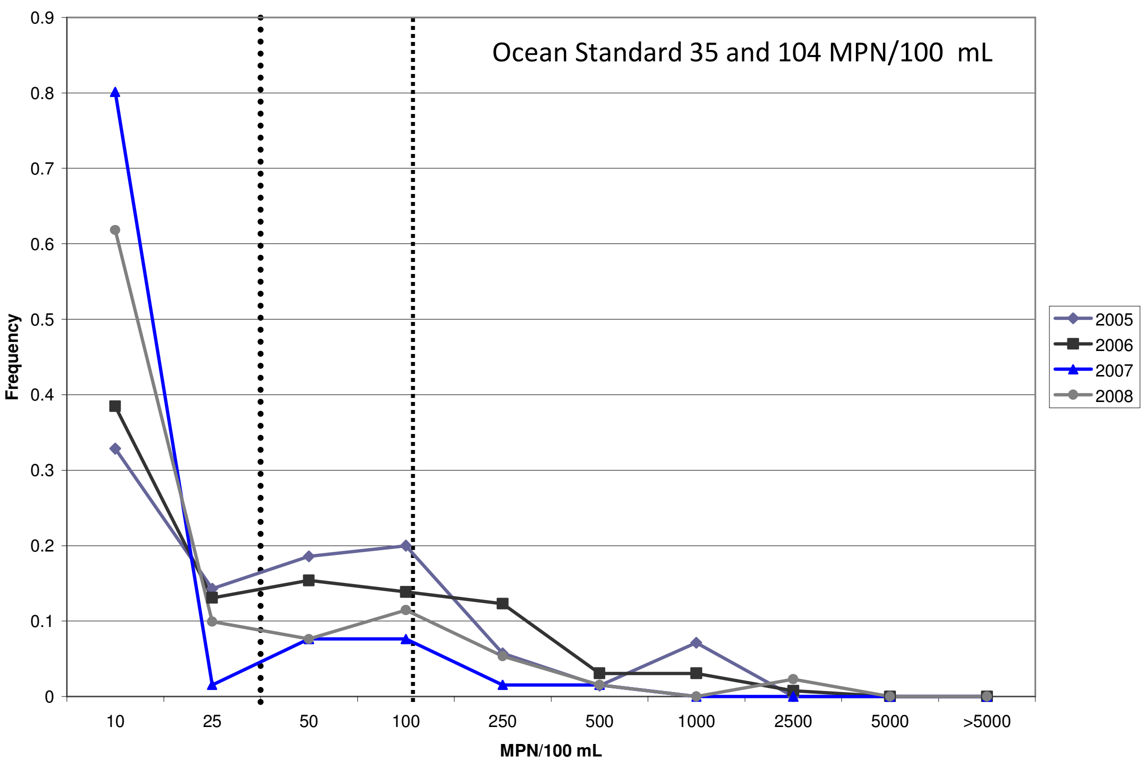
at levels above water quality objectives at Malibu Colony (MC-1), Surfrider Beach (MC-2), and Malibu Pier (MC-3). The pollution on beaches has been quantified in the 2003 303(d) list, Heal the Bay's beach quality grades, and the Regional Board's Santa Monica Bay Bacteria TMDLs. Further, the Regional Board issued a Notice of Violation (NOV) for bacteria at the Malibu Civic Center beaches in March 2008. It identified violations of the waste discharge requirements established in Board Order No. 01-182, as amended by Order No. R4-2006-0074 and Order No. R4-2007-0042, Board directions which constitute the Los Angeles MS-4 Permit controlling urban runoff and stormwater discharge. The NOV identified 493 days and 836 instances in the City of Malibu during the summer of 2007 when water contact recreation objectives were exceeded. Of these exceedances, seventy single sample violations occurred adjacent to the Malibu Civic Center.

Enterococcus on Malibu Civic Center Beaches and all Santa Monica Bay Beaches

The enterococcus measures recorded on beaches at the Malibu Civic Center area over the summers 2005 to 2008 were sorted by interval frequency and plotted against the percentage of the total number of measurements. The method was chosen to minimize the impact of varying sample sizes and simplify large variations in the measures.

The Civic Center beaches were found to have enterococcus frequency distributions with correlation coefficients which demonstrate that the distribution of bacteria frequencies is consistent at a beach, and not a function of external events such as swimmer shedding, the inappropriate disposal of a diaper or beach use by a homeless person.

Figure 6. Surfrider Beach MC-2 Enterococcus Interval Frequency for May-October Summer Single Measures (Correlation coefficients of the frequency distribution ranges from .82 to .99: see discussion in Attachment 3-1)



DRAFT JULY 31 2009

Figure 7. Malibu Colony MC-1 Enterococcus Interval Frequency for May-October Summer Single Measures

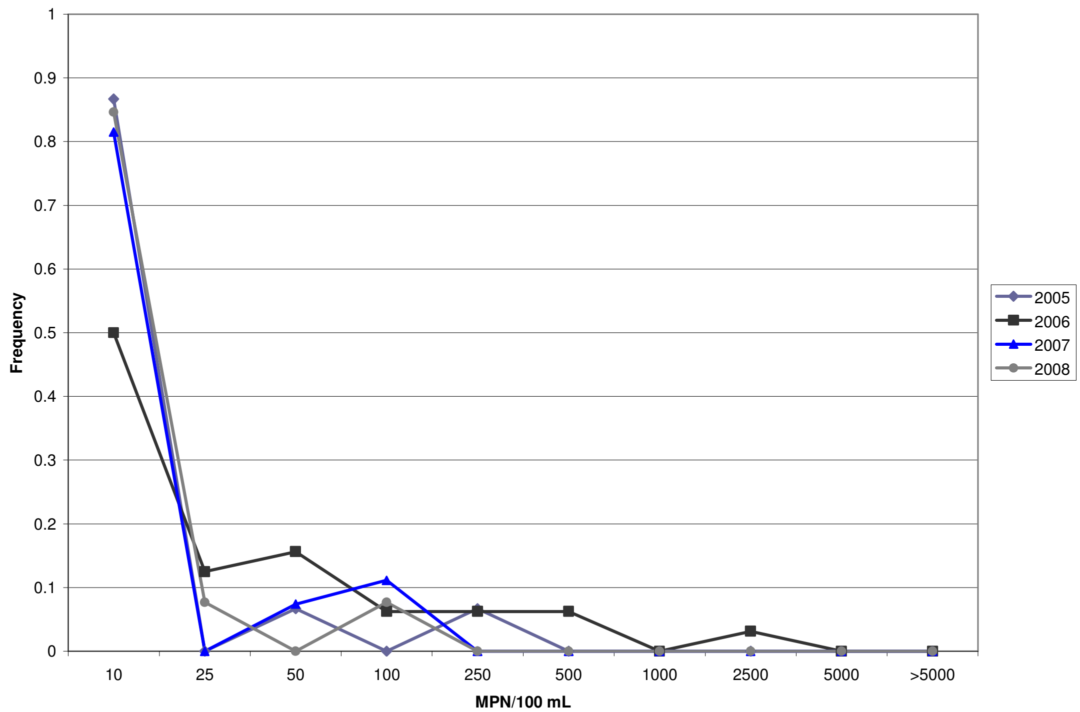
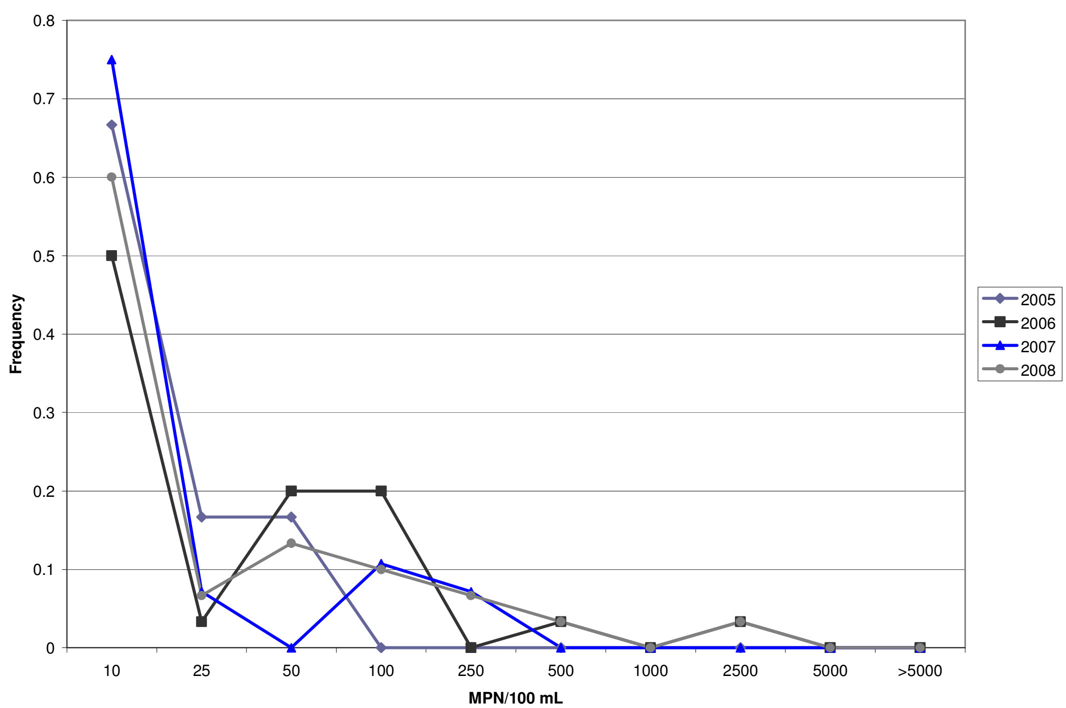
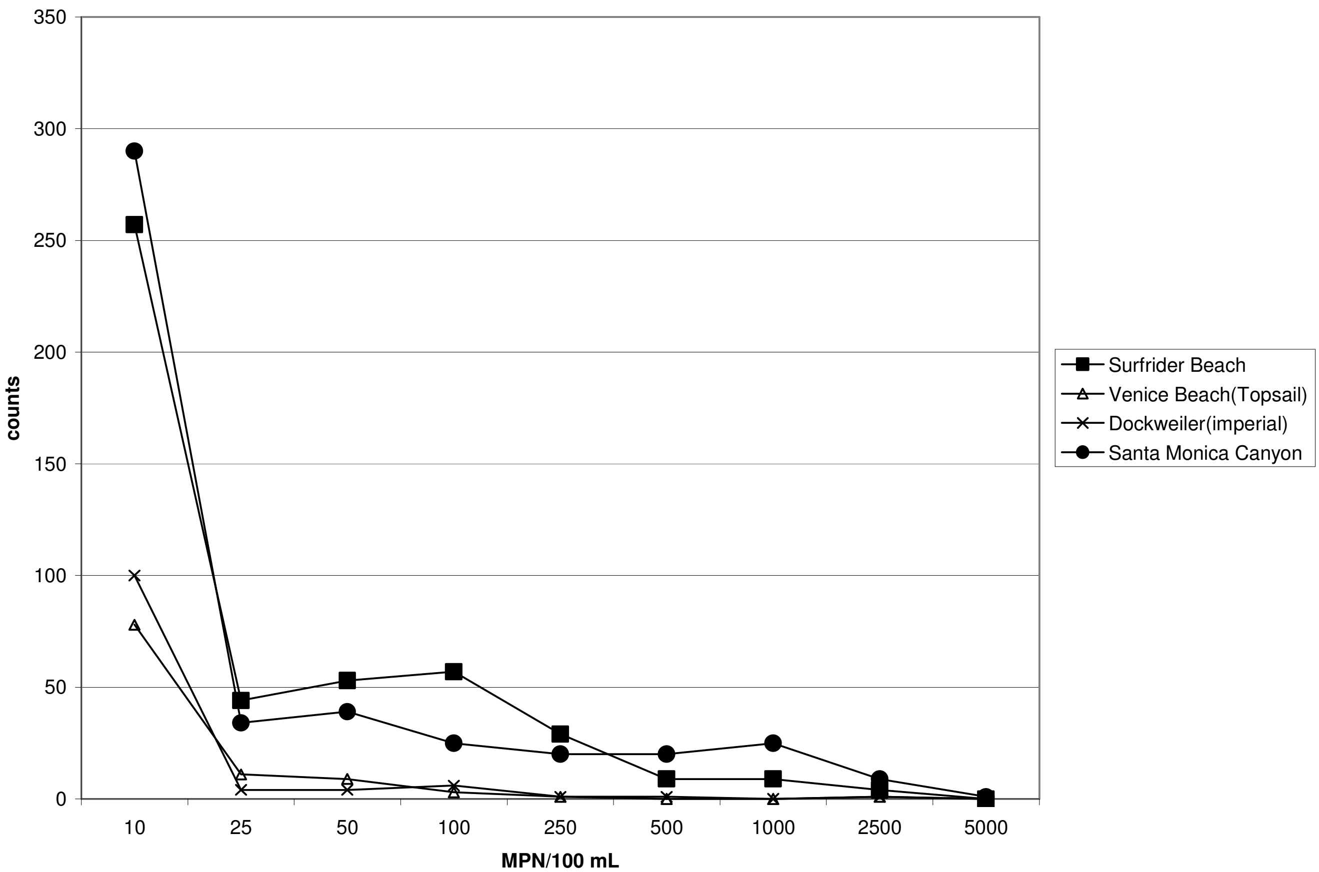


Figure 8. Malibu Pier MC-3 Enterococcus Interval Frequency for May-October Single Measures



The enterococcus interval frequency distribution at the Malibu Civic Center beaches (septic beaches) are both similar and distinct from those found for other individual beaches, as in this comparison of the septic Surfrider Beach and Santa Monica Canyon, Venice Beach at Topsail and Dockweiler Beach at Imperial, all of which are sewered. All four beaches are near to a freshwater discharge point for a large watershed area and have heavy public use. In this particular graph, values below 10 MPN/100 mL were not included and counts are displayed instead of frequency.

Figure 9. Surfrider, Santa Monica Canyon, Venice and Dockweiler Beaches Enterococcus Interval Counts for May-October Summer Single Measures for 2005-2008 without values <10 MPN/100mL



The Malibu Civic Center beaches were found to have enterococcus frequency distributions similar to those for all Santa Monica Bay Beaches in that they had the most measures at 10 MPN/100 mL and some additional measures above 1,000 MPN/100 mL. Figures 10-13 and Tables 4-7 of all Santa Monica Bay beaches for 2005 through 2008 show that these general characteristics are present for all the studied beaches.

Figure 10. 34 Santa Monica Bay Beaches 2005 (All MS-4 beaches without direct ocean discharge to waves) Enterococcus Interval Frequency for June-August Single Measures

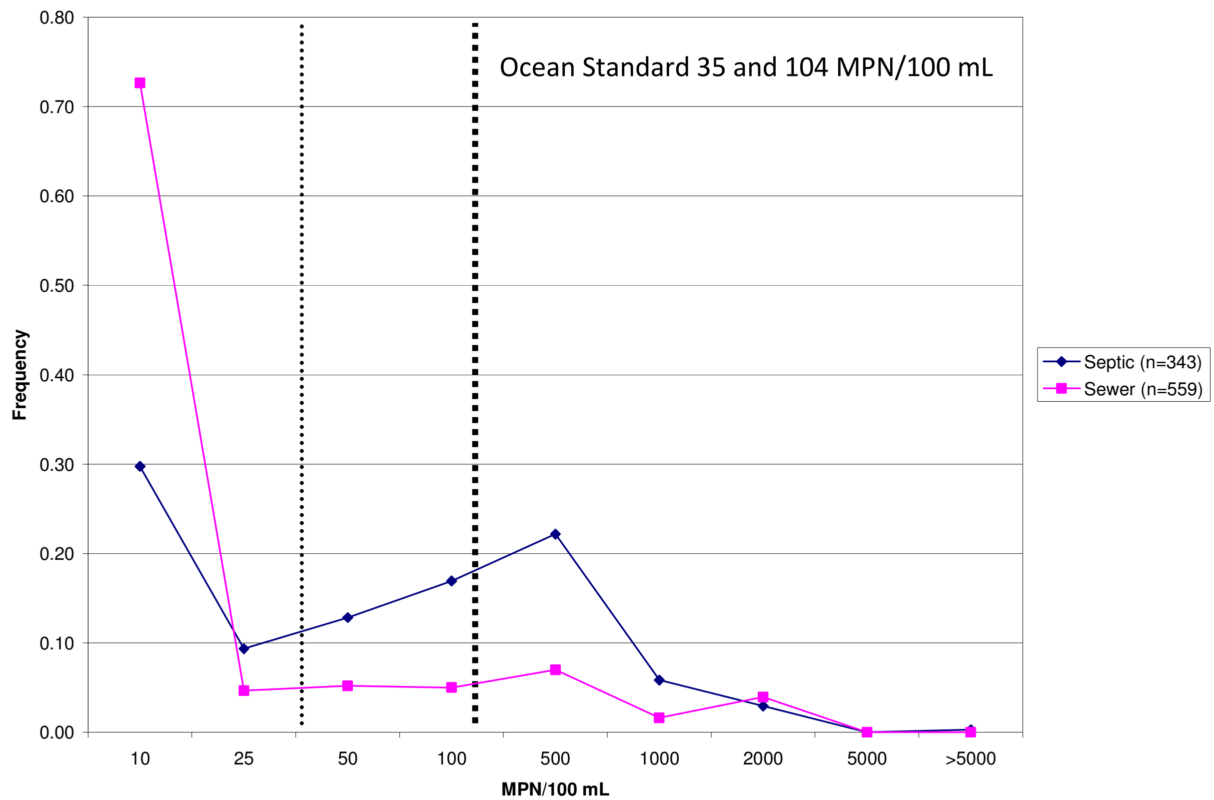


Table 4: Relative Number of Exceedances for 58 Septic and Sewered Beaches in 2005.

In MPN/100mL	all beaches in 2005			
Enterococcus	Septic (n=466)	% total days reported at septic sites	Sewer (n=859)	% total days reported at sewer sites
Days above 35	206	44%	207	24%
Days above 104	108	23%	126	15%

Figure 11. 34 Santa Monica Bay Beaches 2006 (All MS-4 beaches without direct ocean discharge to waves) 1nterococcus Interval Frequency for May-October Single Measures

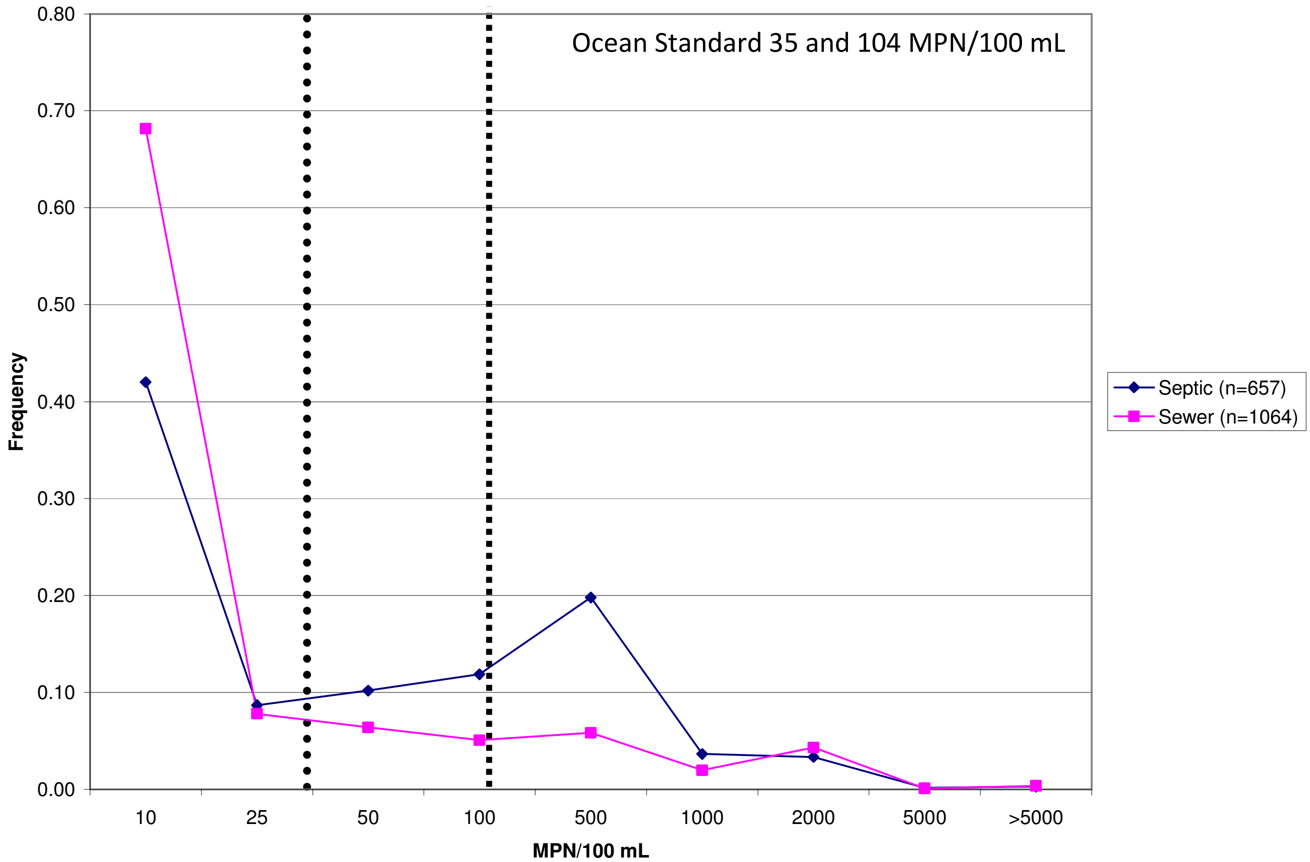


Table 5: Relative Number of Exceedances for 58 Septic and Sewered Beaches in 2006. Sewered beaches were tested about one and a half times as often, in this year, as septic beaches, yet more days were recorded when enterococcus densities on septic beaches were higher than the Ocean single sample and geometric mean objectives.

In MPN/100mL	all beaches in 2006			
Enterococcus	Septic (n=903)	% total days reported at septic sites	Sewer (n=1669)	% total days reported at sewer sites
Days above 35	326	36%	295	18%
Days above 104	183	20%	156	9%

Figure 12. 34 Santa Monica Bay Beaches 2007 (All MS-4 beaches without direct ocean discharge to waves) Enterococcus Interval Frequency for May-October Single Measures

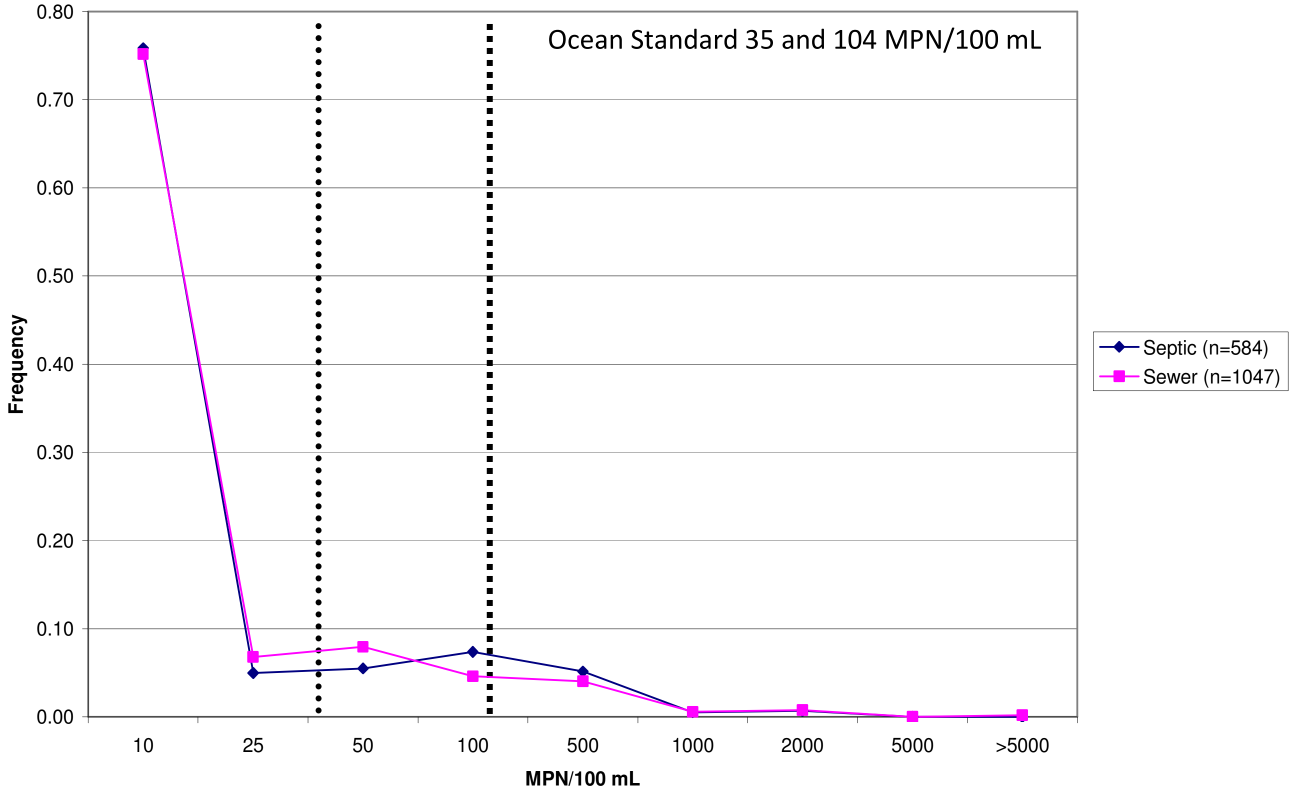


Table 6: Relative Number of Exceedances for 58 Septic and Sewered Beaches in 2007. Sewered beaches were tested about twice as often, in this year, as septic beaches, and both had the same frequency of exceedances.

In MPN/100mL	all beaches in 2007			
Enterococcus	Septic (n=816)	% total days reported at septic sites	Sewer (n=1705)	% total days reported at sewer sites
Days above 35	106	13%	215	13%
Days above 104	38	5%	79	5%

D R A F T J U L Y 3 1 2 0 0 9

Figure 13. 34 Santa Monica Bay Beaches 2008 (All MS-4 beaches without direct ocean discharge to waves) Enterococcus Interval Frequency for May-October Single Measures

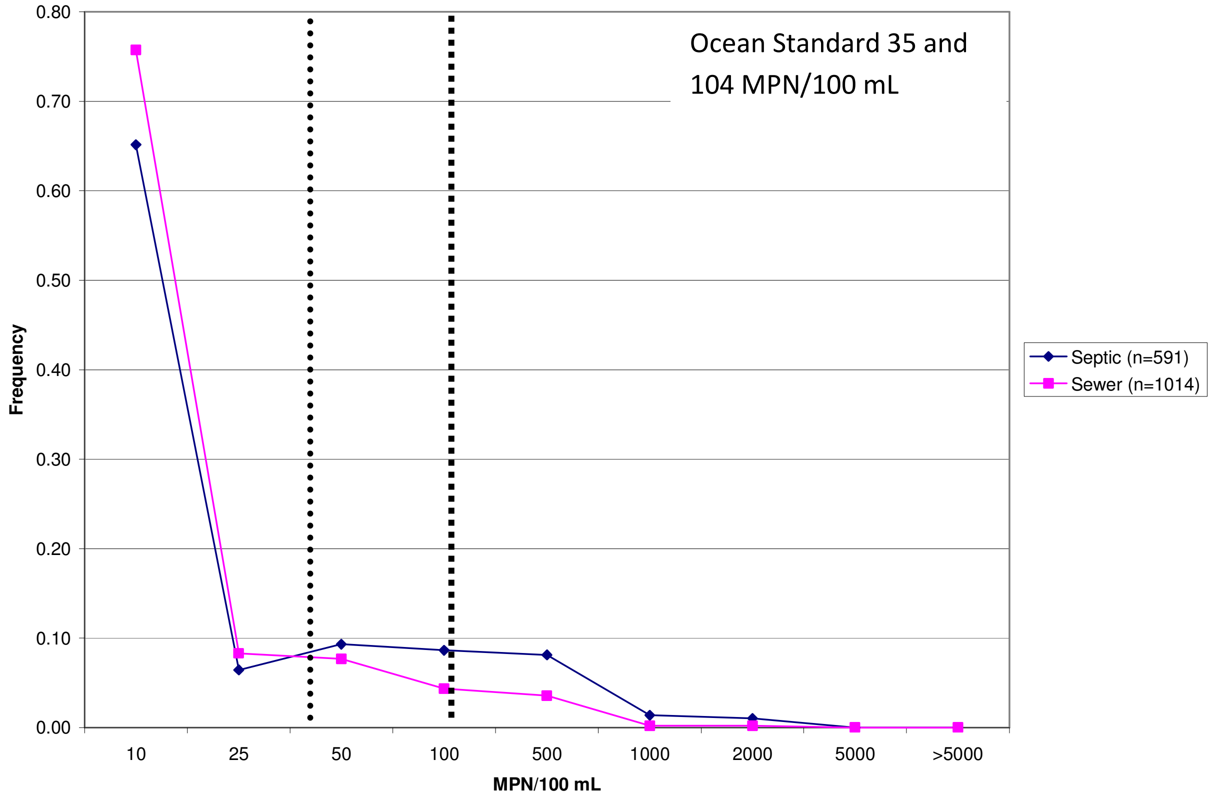


Table 7: Relative Number of Exceedances for 58 Septic and Sewered Beaches in 2008.

In MPN/100mL	all beaches in 2008			
Enterococcus	Septic (n=813)	% total days reported at septic sites	Sewer (n=1644)	% total days reported at sewer sites
Days above 35	145	18%	176	11%
Days above 104	59	7%	54	3%

This general comparison between Civic Center Beaches and all Santa Monica Bay beaches is consistent with the hypothesis that the mechanism(s) supplying enterococcus bacteria to beaches during the summer months does not operate uniformly every year. Further, the mechanism which supplies enterococcus bacteria to the beaches at levels of 10 MPN/100 mL, and to a lesser extent at levels above 1,000 MPN, must operate on all beaches regardless of the year or the method of waste treatment in the adjacent area.

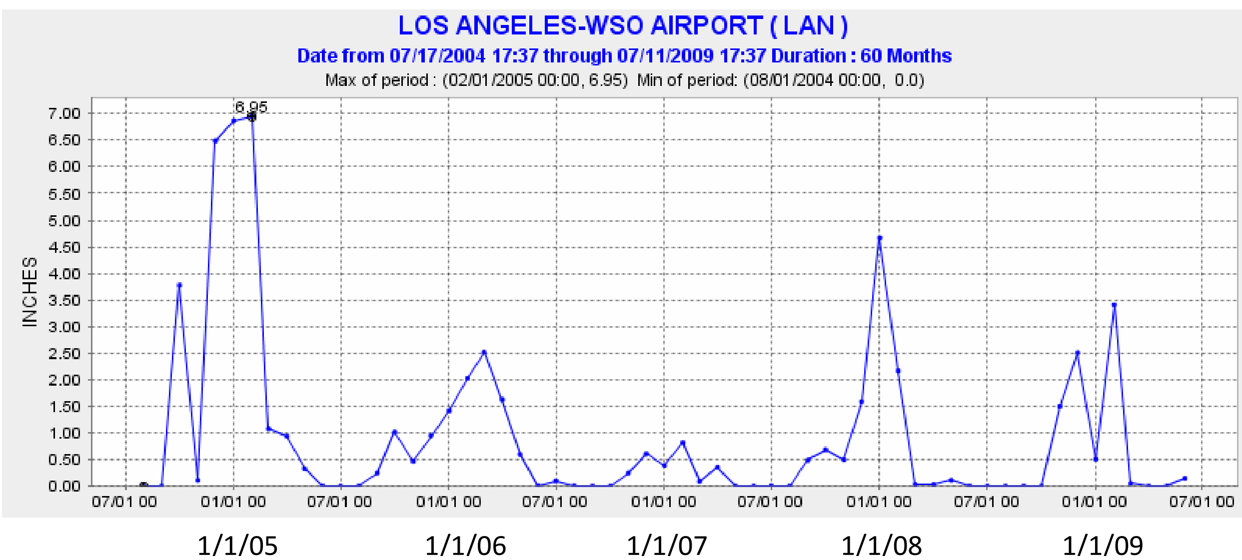
Statistic analysis is performed for the same data sets of 2005-2008 using Gehan Test (a non-parametric Statistical Program) from USEPA ProUCL Statistical Program. All results confirmed hypothesis that enterococcus concentrations at septic beaches are greater than sewered beaches with 95% confidence level except 2007 data. Gehan Test results are included in Attachment 3-1. *Rainfall and Bacteria*

Examination of all Santa Monica Bay beaches over four years provides evidence that bacteria are transported by groundwater to the beach face. Because bacteria must be transported by the groundwater between the septic systems and surface receiving waters and groundwater gradients increase after rain, a correlation between the number of enterococcus measures per site and the rainfall is expected at beaches where groundwater movement of the bacteria takes place.

Rainfall and Enterococcus

The highest monthly volume of rain fell in 2005 (wet year), among the years evaluated here, when 6.95 inches were recorded. The lowest was reported in 2007 (dry year) when less than one inch was recorded. However, the average annual rain fall in this area is 12 inches per year, significantly larger than the rain received in this study's "wet" year of 2005. Rain gauge reports from Los Angeles International Airport reported by the Department of Water Resources confirm annual variations in precipitation by year and are shown in Figure 14.

Figure 14. Rain gauge information for Los Angeles International Airport (elev.100 feet)



Septic beaches are more distinct from sewered beaches in summers preceeded by rainy winters. The relative frequency of bacteria densities above 35 MPN/100mL on the beaches during the summer are seen to decrease between 2005 and 2007 in Tables 4 through 6. The rainfall also decreases during this period as shown in Figure 14.

Non parametric statistical tools were applied to the enterococcus beach data sets using Gehan Test from EPA's ProUCL statistical program. Using Form 1 Test, the Null Hypothesis is "Septic Beach

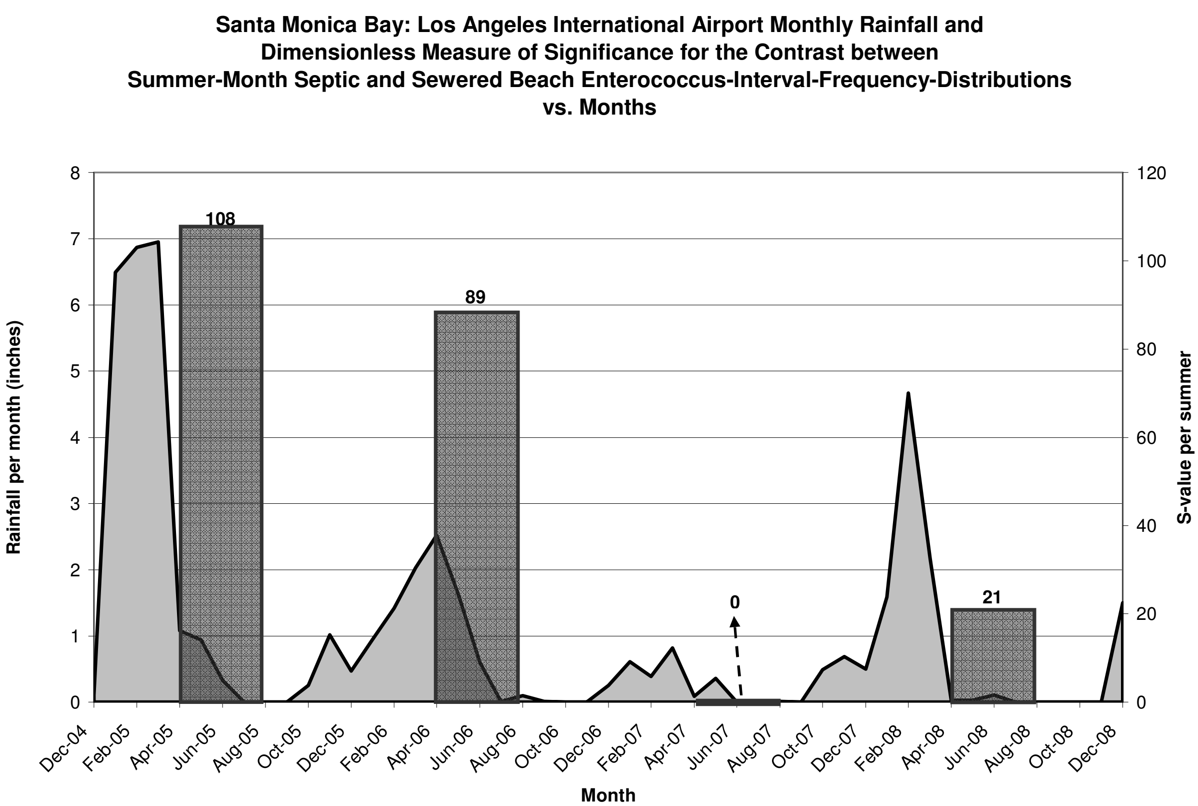
Mean/Median Less Than or Equal to Sewer Beach Mean/Median;" and the Alternative Hypothesis is "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median". The result of the Gehan Test for 2005, 2006 and 2008 shows that the Null Hypothesis is rejected by a low P-value with an alpha value of 0.05 (a confidence level of 95%) , which rejects the Null Hypothesis and supports the Alternative Hypothesis "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median".

The statistical assessment of the 2007 enterococcus data is not consistent with the statistical results for 2005, 2006, and 2008. The same results were also obtained with an alpha value of 0.01 (a confidence level of 99%); enterococcus concentrations at septic beaches are higher than concentrations at sewered beaches statistically. Form 2 Test is also performed using the Gehan Test to verify the above conclusions.

The "Substantial Difference" (S) is used to estimate the difference in enterococcus concentration between septic and sewered beaches and is shown in Figure 15. The rainfall was low in 2007, as is the S value. The S increases as the winter rains increase in 2008.

Because septic or sewered beach have no stormwater discharge for June to September, these observations document a supply and transport mechansim. Ground water discharge with elevated enterococcocus densities after wet winters is affecting septic beaches to a greater extent than is occuring on sewered beaches. In the summer of 2008, the frequency of enterococcus densities above 35 MPN/100mL does not increase to the 2006 summer levels, despite increasing rainfall in the winter of 2007-2008, nor does the S value increase to 2006 levels. This observation is attributed to short term rain events in February 2008 when discharge was via stormwater and not groundwater recharge..

Figure 15.



D R A F T J U L Y 3 1 2 0 0 9

* For a discussion of the S value see Attachment 3-1 on statistics.

The number of violations of the Ocean Plan enterococcus objectives, as reported in the 2008 Notice of Violation sent to MS-4 Stormwater dischargers based on the Santa Monica Bay Dry Weather Bacteria Total Maximum Daily Loads, is higher at Civic Center Beach than at beaches with shared physical characteristics. The exception is Santa Monica Pier. It had fewer geometric mean enterococcus exceedances than Malibu Pier and even single sample enterococcus is less likely to be a human-fecal-indicator as summarized in Table 8. In general, septic beaches have higher exceedance of water quality objectives than sewered beaches when similar individual beach data sets are compared.

Table 8: Failure to meet Ocean Standards at Civic Center Beaches and paired beaches

Fecal Indicator Bacteria Violations for Civic Center Beach	Paired Beach	Single Total	Single Fecal	Single Enter	30 day Mean Enter	Objective not achieved	Total Days objective not achieved
Surfrider (MC-2)		7	25	**9**	**8**	132	62
	Santa Monica Canyon(2-7)	0	1	8	0	10	10
	Venice beach Topsail (2-9)	0	0	0	0	0	0
	Dockweiler Imperial (2-13)	1	0	0	0	1	1
Malibu Colony (MC-1)		0	1	**0**	**13**	19	14
	Will Rogers east of Sunset (2-3)			3	3		
	Santa Monica Beach at strand (3-9)			0	0		
	Hermosa Beach at 26th (5-4)			1	1		
Malibu Pier (MC-3)		0	0	**3**	**16**	20	19
	Santa Monica Pier (3-3)	4	96	**15**	**13**	424	236
	Redondo Beach Pier (6-2)			2	2		
	Hermosa Beach Pier (5-5)			1	1		

Human Health Risk from Enterococcus on Civic Center Beaches

A specific measure of the human health risk with enterococcus density is based on an epidemiology study (Cabelli, V.J, 1983 EPA health criteria for enterococcus density in marine recreational waters) which correlates fecal-indicator-bacteria enterococcus, a bacteria species found in the human gut, and increased rates of gastrointestinal illness (flu symptoms) among swimmers who immersed their heads**.** Some of the beaches studied had identifiable sources of treated or untreated human waste entering the marine environment in the vicinity of the beaches, and some did not. All had urban runoff, storm flow and human visitors during the study period.

The swimming-associated gastroenteritis examined in the study is acute, is of short duration and children have the highest attack rates. The symptoms quantified were fever, vomiting, diarrhea, stomachache, and nausea. EPA proposed human rotavirus and/or the parvo-like viruses as etiologic agents. The researchers find "..the etiologic agent(s) for the observed GI [Gastrointestinal] symptomatology is present in sewage in large numbers, that it is highly infective and/or that it survives sewage treatment, disinfection, and/or transport better than the indicator [enterococcus] (page 44)."

EPA counted the immersed-head swimming and non-swimming populations, their highly credible gastrointestinal illness rates and the enterococcus density in the chest-depth water. They found a linear relationship between the swimming associated rate for gastrointestinal symptoms for 1,000 people and enterococcus bacteria density, a relationship depicted for frequency interval in Table 9.

Table 9. Enterococcus Densities and Illnesses among Swimmers

1983 EPA Health Effects Criteria for Marine Recreational Waters (Figure 9, page 43)						
MPN/100 mL	10	50	100	250	500	1,000
Number of illnesses per 1,000 swimmers	9	23	30	40	46	53

Where enterococcus densities are measured and EPA's other assumptions apply, the risk of illnesses per 1,000 swimmers can be estimated using this relationship. If the interval frequencies of enterococcus densities are calculated for a beach over a summer, then that interval frequency (F) at the Santa Monica Bay beaches times the number of illnesses corresponding to the average MPN/100 mL of the interval (N), from the EPA study quantifies the risk (R) as estimated in the number of illnesses in 100 summer days if 1,000 swimmers swim each day.

F (Frequency for range of MPN/100mL) **X** **N** (Number of illness for average MPN/100ML) **= R** (Risk or number of illnesses).

EPA's criteria have been applied to enterococcus bacteria delivered in stormwater flow across a beach into the Santa Monica Bay, similar to the river influent cases in New York. It has also been applied where no surface flow exists between the influent drain or river and the beach monitoring site, like the case in

Boston Harbor, where increased enterococcus densities are related to transport of bacteria from the Ocean or through the beach subsurface.

Since the EPA criteria were developed, some authors (Yamahara, 2008) have questioned its application where an ocean outfall of untreated or partially treated sewage is not present. The EPA study is used here because the illness rates were also based on beaches with no identifiable source of human sewage.

Human viruses, have been found in Malibu Lagoon and Ballona Creek as described in Dr. Mark Gold's 1994 thesis. The source of the viruses are identified as urban flows/stormwater and septic discharge. An elevated risk that enterococcus bacteria indicate human fecal pathogens and viruses could be inferred to exist at beaches adjacent to septic systems, receiving surface flows which discharge directly into the wave wash, and adjacent to discharging ground water in which human enterococcus is identified and attributed to septic discharge. Table 10 below is based on 2006 data and combines the EPA risk as defined solely by enterococcus frequencies and illnesses among swimmers and an estimated additional risk factor that the enterococcus measured on the beach is associated with human fecal pathogens or human viruses. Selected beaches are ranked by the presence of (a) year-round overland flow across the beach of storm/urban flow like Ballona Creek where human viruses were identified , (b) septic systems within 300 feet of the tributary channel or the beach like Malibu Lagoon where the viruses were found, or (c) groundwater concentrations of enterococcus above 1 MPN/ 100 mL within 300 feet of the tributary or channel adjacent and related to leach field discharge of human waste. A ranking of 'High' means that all of these factors are present, a ranking of "Moderate" means that two of these factors are present, and a ranking of "Low" means that one of these factors is present. "None" means that none of these factors are present.

The beaches adjacent to the Malibu Civic Center show the highest combined risk based on possible illness related to enterococcus levels and an increased likelihood of the presence of human fecal pathogens and viruses.

Table 10: Combined Measures of Risk for Human Health- individual Santa Monica Beaches (2006).

Site	**1983 EPA health risk (Additional illnesses)**	**Additional risk factors for human enterococcus***	
SMB 1-12	43	High	Marie Canyon Stormdrain on Puerco Beach
SMB 1-07	27	High	Ramirez Canyon at Paradise Cove Pier
SMB MC-02	22	High	Breach of Malibu Lagoon/Malibu Beach
SMB MC-03	20	High	Malibu Pier on Carbon Beach
SMB MC-01	19	High	Malibu Point on Malibu State beach
SMB 1-10	24	Mod	Solstice Creek at Dan Blocker Beach
SMB 1-18	21	Mod	Topanga Canyon on Topanga State Beach
SMB 2-07	17	Mod	Santa Monica Canyon ##
SMB BC-01	13	Mod	Ballona Creek##
SMB 1-08	27	Low	Escondido Creek
SMB 1-09	19	Low	Latigo Canyon
SMB 3-03	18	None	Santa Monica Pier Stormdrain/Beach##
SMB 5-02	17	None	28th Street Drain, Manhattan Beach##
SMB 3-04	12	None	Pico-Kenter Storm Drain##

*risk factors are (a) groundwater enterococcus levels above 1 MPN/100mL, (b) adjacent septic systems, and (c) surface flow across the beach face. ## sewered beaches. Enterococcus levels were not found to correlate with increasing watershed size among MS-4 beaches and were not found to correlate with other possible sources of human enterococcus such as beach attendance or with possible elevated rates of enterococcus preservation such as low wave strength (Yamahara 2007).

Risk at Septic Beaches compared to Risk at Sewered Beaches

A comparison of estimated illness risk for 13 septic and 21 sewered beaches[2], using only the EPA criteria and the MS-4 interval frequency curves for the wettest summer of 2005 results in a risk of 22 illnesses among swimmers for all septic beaches and a risk of 16 swimmer illnesses for all sewered beaches for 100 days with 1000 swimmers at all beaches or 10,000 swimmers at all Santa Monica Bay beaches over 10 days.

For 2006, 22 illness are predicted for 13 septic beaches for every 1000 summer swimmers and 16 for 21 sewered beaches for every 1000 swimmers. While the illness risk for 2007 is the same, the risk of illness in the wet year of 2008 is 15 for septic beaches and 13 for sewered beaches.

This risk calculation assumes that human viruses are equally likely to be indicated by enterococcus at all beaches. More human illnesses are expected at septic beaches because the supply of human fecal material is larger, as described above based on 2005 to 2008 data.

Waste Discharge Treatment and Human Health Risk

About 300 Malibu Colony residences can be counted from aerial photo interpretations after 1955 on US Geological Survey topographic maps at a beach bar with 6,000 feet of ocean front. The width of the developed area of the Colony is estimated at 500 feet for a total area of 3,000,000 square feet. Because 43,560 square feet constitutes an acre, the septic density for Malibu Colony is about 4 septic systems per acre.

Septic systems have been shown to discharge to the surface in the vicinity of the leachfields/seepage pits and this process has been linked to increased illness in children. As a result, increased septic system density is also related to an elevated human health risk. In M.A. Borchardt et.al**,** "Septic System Density and Infectious Diarrhea in a Defined Population of Children" in May 2003 (*Environmental Health Perspectives* Vol. 111, No. 5), an 8% increase in the risk of viral diarrhea illness was associated with an additional septic holding tank per 640 acres and a 20% increase in bacterial diarrhea was related to an additional septic holding tank in 40 acres. For reference, the density of septic systems in Malibu Colony is much higher, about 4 per acre. The author states "consumption of well water was not a likely transmission route of bacterial infection from nearby septic systems in this study, because bacterial pathogens were not isolated from the wells of case households, although contamination may have been sporadic."

In contrast, a high level of effectiveness of sewage treatment in centralized treatment plants has been developed through best management practices (Allen 1949), the National Pollution Discharge Elimination

---

[2] For the purposes of this study, the following site definitions were made: MS-4 Septic (13)1-06, 1-07, 1-08, 1-09, 1-10, 1-11, 1-12, 1-13, 1-18, 4-01, MC-01, MC-02,MC-03; MS-4 Sewer (21) 2-01, 2-02, 2-06, 2-07, 2-10, 2-11, 2-13, 2-15, 3-01, 3-02, 3-03, 3-04, 3-05, 3-06, 3-07, 3-08, 5-02, 5-03,6-01,6-05,BC-01; Non MS-4 Septic (9)1-01,1-02,1-03,1-04,1-05,1-14,1-15,1-16,1-17; Non MS-4 Sewer (15) 2-03,2-04,2-05,2-08,2-09,2-12,2-14,3-09,5-05,5-04,5-05,6-02,6-03,6-04,6-06

System and the State of California's Title 22 regulation. State and Federal regulations now require that when treated sewage is discharged in large quantities (above 50,000) gallons per day, viruses must be 99.9% deactivated by ultra violet or chlorine disinfection before possible human contact is allowed. Even advanced on-site wastewater disposal systems in the Malibu Civic Center area have high failure rate of disinfection as shown in Table 1.

<u>4. Discussion of Historic and Recent Studies</u>

Historic Studies relating Malibu Civic Center Septic Systems to Human Health Risk and Beach Pathogens

Existing technical studies (summarized in Table 11) link septic systems at the Malibu Civic Center area to beach bacteria and are discussed below:

On February 5, 1970, Los Angeles County Health (now California Department of Public Health or CADPH) provided a letter to the Regional Board stating that serious potential hazards to human health were expected to result from septic systems. CADPH has repeatedly closed Surfrider Beach at the Malibu Civic Center due to high bacteria concentrations.

On July 8, 1987, Los Angles County Public Works held a public meeting to discuss a Draft Environmental Impact Report for a centralized waste water treatment plant and sewer for Malibu to address human health risk caused by septic system pathogens. The City of Malibu subsequently incorporated and a group of citizens brought a lawsuit to block the formation of assessment districts. The legal settlement required the new City of Malibu to provide sufficient oversight of on-site waste water treatment facilities such that they would meet Regional Board requirements.

The 1994 Ph.D. thesis of Dr. Mark Gold "What are the health risks of swimming in the Santa Monica Bay?" identified human viruses in Malibu Lagoon and identified a source of the contamination as adjacent septic systems.

On December 12, 2002, the Regional Board adopted a Resolution amending the Santa Monica Beach bacteria TMDL to the Basin Plan. The staff report found that bacteria loads from septic systems contribute to beach pathogens.

On August 30, 2004, the Stone report found that bacteria in the groundwater may enter receiving water where septic systems are found within 6 month groundwater travel time of the Ocean or Malibu Creek.

The September 17, 2004, Memorandum of Understanding between the City of Malibu and the Regional Board stated that "ordinances shall be drafted by staff, and recommended for adoption within the six-month-time-of-travel zone, as identified in the Risk Assessment Report (Stone), to provide advanced treatment and disinfection. The six-month time-of-travel zone shall include all areas contributing to Malibu Creek and Lagoon, and beaches between Sweetwater Canyon outfall and Winter Canyon outfall. OWTS located outside of the six-month-travel-time zone that cannot demonstrate compliance through inspection or that are identified as impacting groundwater by any other means shall provide adequate vertical separation and/or advanced treatment with disinfection." As of the date of this document, the City of Malibu has not provided documentation that systems within the six-month-time-of-travel zone have been upgraded to prevent bacteria discharge to the subsurface or include disinfection, nor has an ordinance to this effect been passed by the City of Malibu.

On Dec. 13, 2004, the Regional Board adopted a Resolution amending the Malibu Creek and Lagoon Bacteria TMDL to the basin plan. The staff report references a surface water model prepared by Tetra Tech which quantifies bacteria loads provided by septic systems in the Malibu Civic Center.

Numerous studies have been completed to describe the ecosystem, hydrology, land use, possible mechanisms of waste water treatment, and costs to support of policy decisions about bacteria and human health risk in the Malibu Civic Center (Ambrose et. al. 2008; Bing Yen and Associates, 2001; Crawford Multari and Clark Associates, 1997, 2006, 2007; Ensitu Engineering, 2008; Gold, 1994; Jones and Stokes, 2008; REGIONAL BOARD, 1972, 1998, 1990, 2002, 2004b, 2008, 2008b; Lucero, 2008; Warshall, 1992; Questa, 2003; RMC, 2008; SMBRP, 1999, 2001; UCLA, 2000; URS Greiner, 1999; EPA, 2003; Stone, 2004a, 2004b, 2004c; Trim, 1994; Thorsen, 2008; and Van Beveren, 2008a, 2008b, 2008c).

Table 11: Historic Findings of Human Health Risk related to Malibu Septic System Use.

Date	Source	Summary
Feb 5, 1970	LA County Flood letter to Regional Board	Future septic systems will pollute groundwater in Malibu Creek with nutrients
Feb 5, 1970	LA County Health (now CA DPH) to Regional Board	Serious potential hazard to health from septic systems
Feb 11, 1970	CA DWR to Regional Board	Malibu Valley needs an area wide Water Quality plan
Apr. 8, 1970	Public Hearing SWRCB	Discontinue septics, continue Regional Board surveillance
Jan. 21, 1971	CA DPH Status Ocean and streams in Malibu	Local ocean and freshwater bacteria exceed shell fish collection in areas of development
Mar. 12, 1971	Regional Board EO to LA County Supervisors	Sewer for Malibu must be provided
May 31, 1972	Regional Board Resolution 72-4	Waste Discharge Requirements only allowed if a timetable is established to provide future connections to LA County sewer
Apr. 10, 1985	CA DPH to LA County Supervisors	Staff report and recommendation to authorize Sewer districts
July 8, 1987-Nov. 30 1988	LA Public Works Public Meeting and Malibu Citizens Committee public meetings	Draft Environmental Impact Report for Sewer, discussion of Malibu incorporating, discuss alternatives for centralized system with wetland treatment
Jan. 18, 1989	LA County Supervisors hearing	STEP WWTP system construction approved

1992	Warshall et. al. report finalized	Septic systems in Malibu described. Pathogen removal quantified. Author states that systems require extensive management and recommends centralized system in some areas like Civic center
1994	Thesis Dr. Mark Gold	Three studies between 1990 and 1992 show high fecal-indicator-bacteria frequencies at ankle-depth wave wash and human viruses in runoff from three storm drains in Santa Monica Bay.
Dec. 14, 1998	Regional Board Resolution 98-023	Directs Report of Waste Discharge for all septics and ACL to City of Malibu
Aug 12, 1999	Regional Board Resolution 99-13	El Rio Septic staff report: Poorly maintained septics linked to nitrogen contamination in groundwater
1999	Dames and Moore study	Salt tracer, no pathogens found in wells within 200 feet, but tidal reversal confound results
1999	URS Greiner study	Salt Tracer found at 20 feet in wells, but pathogens not seen in short period test.
Dec. 12, 2002	Regional Board Resolution	Santa Monica Bay bacteria Total Maximum Daily Load: beach pathogens attributed to loads from septic systems
March 21, 2003	EPA Malibu Creek Nutrient TMDL	Total Maximum Daily Load sets loads and numeric targets for total Nitrogen
2003	Questa study	Groundwater discharge to receiving water, quantified including volume from septic system discharge.
Aug 30, 2004	Stone study	Bacteria may enter receiving water where septic systems are found within 6 month travel time
Dec. 13, 2004	Regional Board Resolution	Malibu Creek and Lagoon TMDL: Tetra Tech surface water model sets loads for bacteria from septic systems
March 2006	Richard Viergutz, M.S. Thesis	Discharge of sewage-polluted groundwater into Malibu Creek and Lagoon resulting from groundwater surface interactions

Recent Studies relating Septic Systems to Beach pathogens

Research completed over the last ten years has expanded the understanding of beach bacteria sources and mechanisms of transport. For example, it has been demonstrated that the fecal-indicator-bacteria enterococcus is present on all California beaches, a contamination that is related to both human and non-human sources (Yamahara, 2007) and can be associated with septic system effluent (Boehm et. al., 2004; De Sieyes et. al , 2008). Enterococcus can be transported, stored and, under some conditions, grown in the beach environment. Groundwater transport of bacteria occurs and has been related to nitrogen levels from on-site wastewater treatment systems.

In 2003, Mark Borchardt and others reported in Environmental Health Perspectives, Vol. 111, No. 5 that the density of septic systems correlated with increased rates of infectious diarrhea in children in central Wisconsin. Fecal enterococcus bacteria were one of the indicators used to denote the presence of human pathogens. Borchardt found that viral diarrhea increased by 8% for every additional holding tank in 640 acres and bacterial diarrhea increase by 22% for every additional holding tank in 40 acres. While household wells were sampled for bacterial, risks relate to surface contact with pathogens near septic systems.

In 2004, Alexandria Boehm and others reported in Environmental Science and Technology Vol. 38, No. 13 that groundwater discharge of microbial pollution moved from a shallow beach aquifer on to the beach face at Huntington Beach. While fecal-indicator-bacteria were found in only one groundwater sample, column studies show that the transport of enterococcus is not inhibited by sand collected in the field. In addition, radon isotopes characteristic of groundwater linked 38% of the enterococcus variation to groundwater discharge.

In 2007, Kevin Yamahara and others reported in Environmental Science and Technology, Vol. 41, No. 12, that 91% of sampled California coastal beaches had enterococcus. The presence of a source, such as a river, wave shelter and surrounding anthropogenic land use correlated with a significant portion of the population variation. An enterococcus gene study identified a human fecal source in a nearby storm drain.

In 2008, Nicholas De Sieyes and others reported in the Journal of Limnology and Oceanography Vol. 53, No. 4, that fresh nutrient-rich groundwater discharges in fortnightly pulsing into the ocean across a beach. While fecal indicator bacteria and human gene analysis found in monitoring wells were attributed to pollution from adjacent septic systems, the concentrations of these pathogens did not increase with nutrients.

In 2009, Kevin Yamahara and others reported in Applied and Environmental Microbiology, Vol. 75, No. 6, that enterococcus bacteria, related to human enteric disease from swimming in marine waters, can replicate in beach sand with repeated wetting.

In 2009, the American Association for the Advancement of Science summarized studies on Methicillin Resistant Staphylococcus Aureus bacteria (MSRB) found in ocean water and on beaches in Florida in 2009. The bacterial infections are resistant to anti-biotics and are more commonly found in hospitals, but are now known to be transmitted to the beach through contact with infected individuals and, according to one report, through municipal effluent. The ability of the bacteria to travel via sewage has not been quantified.

Other studies have been completed within the last twenty years to characterize pathogen sources and the mechanisms of transport since 1970 when concerns about a human health impact were first discussed for the Malibu Civic Center Area (Bloch, A.B. et. al., 1990; Boehm, A et.al., 2004; Borchardt, M.A. et. al., 2003; Chu A.K. and Sander, B.F., 2008; Cuyk. S.V. et. al. 2004., De Sieyes, N.R., Yamahara, K.M., Layton, B.A., Joyce, E.H., & Boehm, A.B. 2008; Goyal, S.M., & Gerba, C.P. August 1979; Ground Water Monitoring and Assessment Program. May 1999; Noble, R.T, & Fuhrman, J.A.,1996;Schaub, S.A., & Sorber, C.A. May 1977; Schijven, J.F. & Hassanizadeh, S.M. 2002; Stramer, S.L., & Cliver, D.O. 1984;Tiefenthaler, L.L, Stein, E.D., & Lyon, G.S. January 2008; United States Environmental Protection Agency. August 2002;Vaughn, J.M., Landry E.F., Baranosky, L.J., Beckwith, C.A., Dahl, M.C., & Delihas, N.C. July 1978;Yates, M.V., Gerba, C.P., & Kelley, L.M. April 1985;Yates, M.V., Yates, S.R., Warrick, A.W., & Gerba C.P. September 1986;Yamahara, K.M., Layton, B.A., Santoro, A.E., & Boehm, A.B. 2007;Yamahara, K.M., Walters, S.P., & Boehm, A.B. January 6, 2009).

These studies have shown that the beach is a more complex microbiological environment than was previously understood. Familiar fecal-indicator-bacteria like enterococcus have been found in animal and bird (Boehm et. al., 2004; De Sieyes et. al , 2008) feces. Enterococcus has been grown in the laboratory setting from unseeded ocean water samples (Yamahara, 2009) and found in a freshwater environment free from human impact (Tiefenthaler, 2008). Enterococcus has also been shown to persist for later discharge in the beach sand and occur in higher concentrations in organic beach debris (San Diego Regional Board-Newport Bay Total Maximum Daily Loads; Yamahara, 2007).

Anthropogenic enterococcus has been identified in marine water in sheltered urban beaches (Yamahara, 2007) and in nitrogen-rich water (De Sieyes, 2008; Boehm, 2004) attributed to septic discharge from septic systems through the groundwater into the Ocean. Radon rich water associated with groundwater discharge has been related to groundwater discharge of enterococcus on a beach in an urban setting (Boehm et. al., 2004; De Sieyes et. al , 2008).

Recent work also shows that the beach is a more complex hydrologic environment than the steady state condition than had been previously modeled (Stone 2005 Malibu Risk Assessment). Tidal and seasonal (neap and spring) freshwater transport rates have both been reported as higher (Boehm et. al., 2004; De Sieyes et. al , 2008) while ground transport rates during low tide are reported to be higher (Izbicki, 2009). Bacteria have been shown to move unimpeded through field sand samples (Yamahara, 2007). Other workers used sand column studies to show bacteria and virus retention and remobilization was related to the movement of organic material. Sand filtration studies for sewage treatment plants describe 'breakthrough' or bacterial transport for both small (viruses) and large particles (bacteria) in the dynamic condition of 'backwashing' or sand re-packing which takes place in a sand filter and on a beach.

Studies of groundwater do not report bacteria in concentrations consistent with the bacteria measurements taken on the adjacent beach (Boehm, 2004; De Sieyes, 2008). Hydrological mounding beneath the septic areas may affect water table gradients otherwise dependent on tides and freshwater subsurface movement and may result in unpredicted flow paths and either limit or enhance septic discharge (Izbicki, 2009). Similarly, bacteria and viruses have recently been shown to adhere and remain viable in organic material (Yamahara, 2007; Azadpour-Keeley, 2003; Noble, 1996; Schaub, 1997, Schijven, 2002; Stramer, 1984) until remobilized. Other mechanisms which may result in the preservation of enterococcus include elevated nitrogen and/or oxygen levels (Vaughn, 2008; Azadpour-Keeley, 2003; Yates, 1985, 1986) in the subsurface or on the beach face. Further, the subsurface septic plumes have been found to stay intact during subsurface movement (Groundwater Monitoring and Assessment Program: Baxter, Minnesota, 1999).

Possible Sources and Transport Mechanisms for Bacteria in the Malibu Civic Center.

Figure 15 shows the Malibu Civic Center with planned development (Questa, 2003), and the line of the cross section shown in Figure 16. The cross section shows possible paths of transport for the bacteria discharged into septic leachfields/seepage pits to Malibu Creek, Malibu Lagoon and the ocean. Note in the cross section that bacteria leaving septic systems in Malibu Colony or adjacent to Legacy Park have the shortest travel times and fewest opportunities for subsurface physical detention, chemical attack or biological predation.

The movement of bacteria from the Civic Center area north of Pacific Coast Highway via subsurface transport to Surfrider Beach under summer conditions would require preservation or growth of enterococcus and movement through the beach barrier with remobilization in marine water (see Figure 16 [cross section]). Human fecal enterococcus must survive physical, chemical and biological destruction in the subsurface before their discharge, enterococcus from higher elevations within the watershed must travel further and both light and distance are known to cause de-activation of both viruses and bacteria (Azadpour-Keeley, 2003;Yates, 1985, 1986).

Figure 16. Planned development in the Malibu Civic Center from Questa 2003 and cross section line

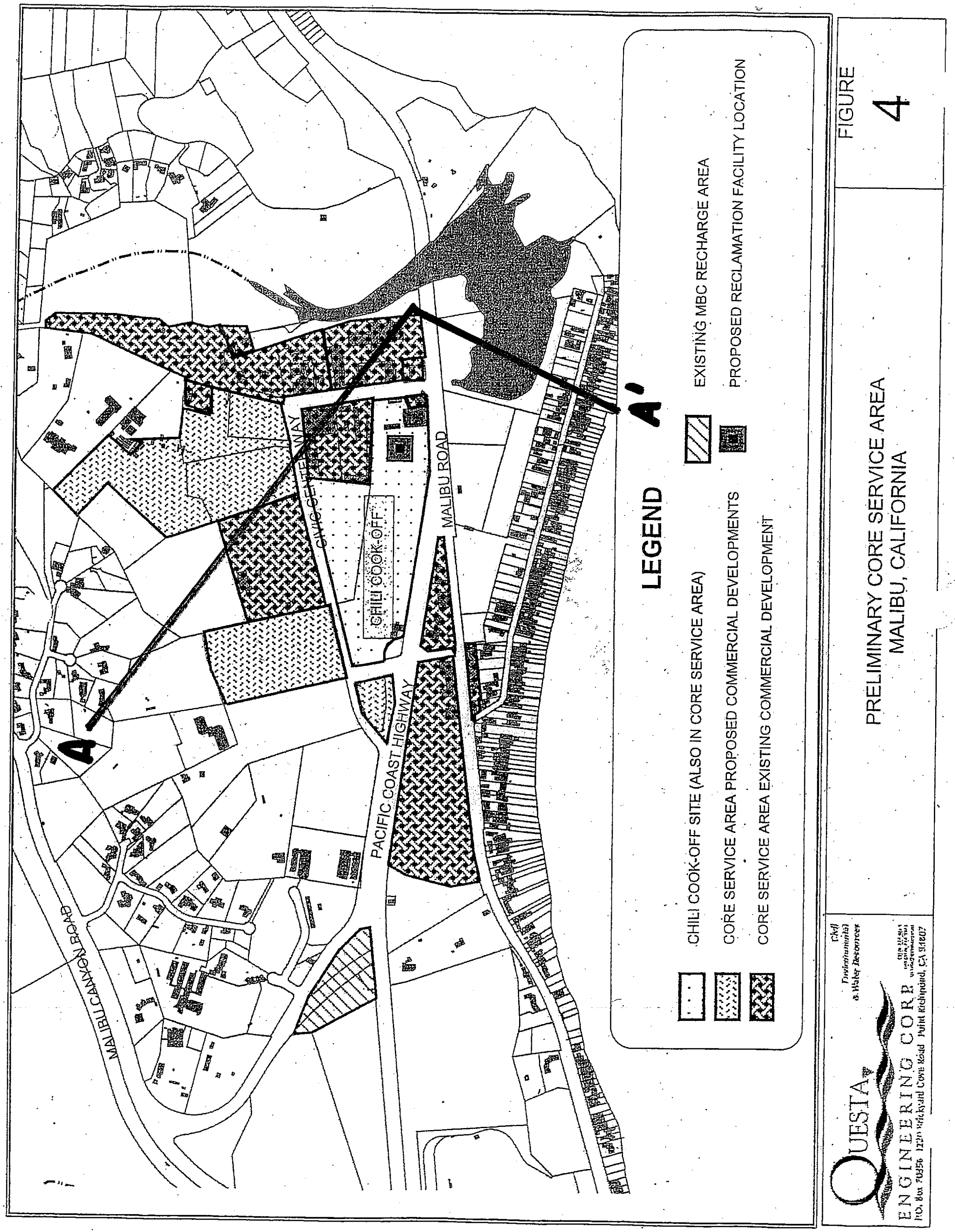
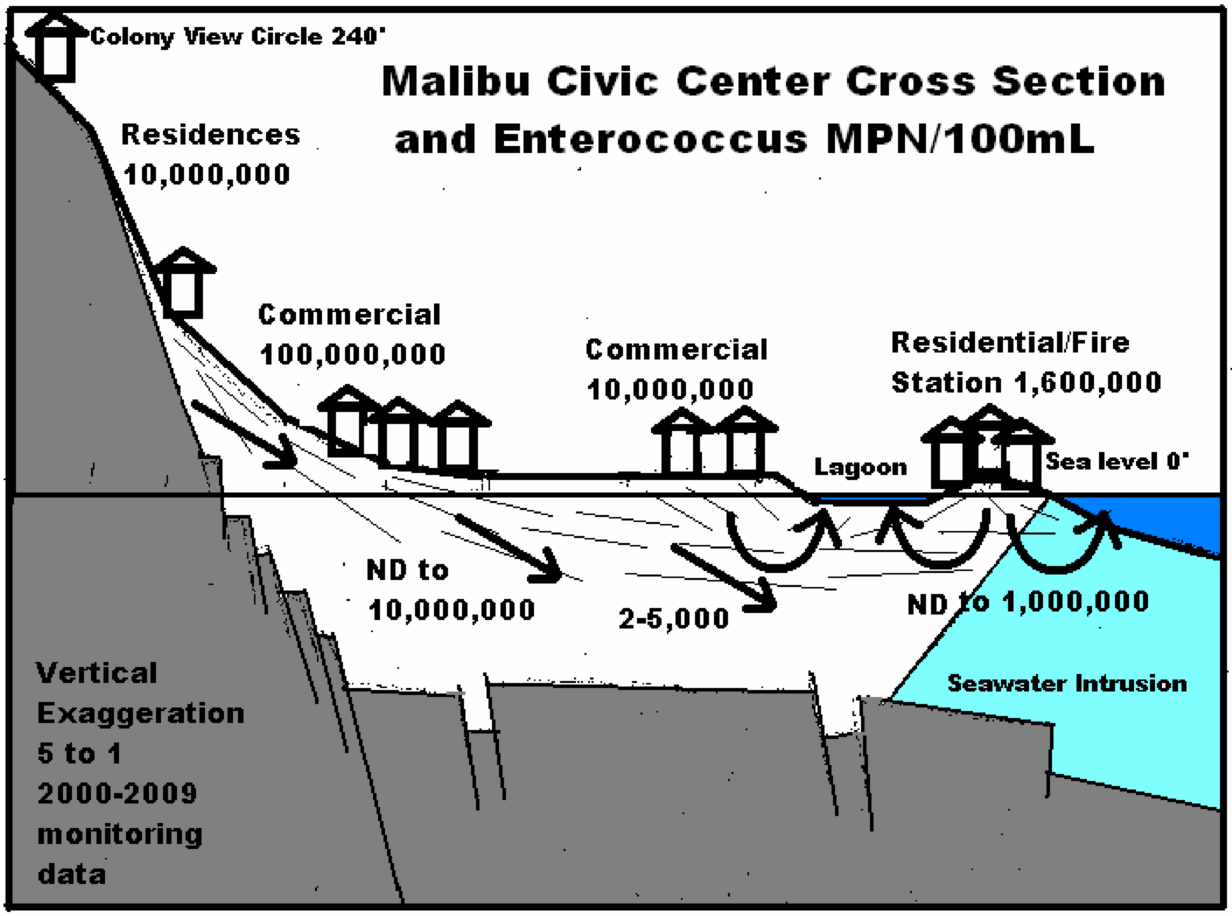


Figure 17. Cross Section A to A' showing facility and groundwater bacteria and flow paths



5. Conclusion

Malibu Creek, Lagoon, and nearby beaches are popular not only within the local community but as a destination for visitors as well. In the Basin Plan, the Regional Board has designated these waters for both water contact recreation (e.g. swimming) and non-contact water recreation (e.g. sunbathing, aesthetic enjoyment), and set standards at levels that will protect human health.

As determined by the Regional Board and US Environmental Protection Agency, surface waters in the Malibu Creek Civic Center area are impaired for water contact recreation, and consistently have failed to meet standards set to protect ingestion of waters by swimmers and surfers. Repeated failures to meet standards set to protect public health has resulted in a 'beach bummer' reputation for Surfrider Beach.

To examine the hydraulic connection of discharges from OWDSs through groundwater to nearby surface waters, staff evaluated more than 8,000 samples of wastewater effluent, underlying or nearby groundwater, and surface waters. Staff determined that pathogens from wastewaters migrate to surface waters and that, consistent with data supporting the designations of impairments, the levels of pathogens do not meet standards protective of human health. Staff also determined that risks of infectious disease from water contact recreation were elevated at beaches in the Malibu Civic Center area versus comparable beaches with sewers.

Staff also reviewed numerous previous studies, and found conclusions from these other studies to be consistent with staff's determination of impairment to the beneficial use of water contact recreation.

ATTACHMENT 3-1: STATISTICS

Statistical Significance

The application of statistical tools to the beach bacteria data sets revealed that standard tests have a high potential to produce misleading results. Additional statistical tests were used to confirm a significant difference between enterococcus interval frequency distributions for septic and sewered beaches in 2005, 2006 and 2007 for non-MS-4 beaches not including beaches with direct discharge to beach wave wash.

The examination of enterococcus on beaches requires the manipulation of very large data sets. As an example, 7,081 measures were collected from beaches receiving MS-4 discharge in the summers of 2005 through 2008. The measures were not all normally distributed and were dominated by densities at or below 10 Most Probable Number (MPN)/100 mL (considered to be non-detect), with the presence of occasional measures above 24,000 MPN/100mL. The majority of the bacteria measures in the beach data sets had low and high enterococcus densities which together constitute a log normal distribution, but with interval frequencies between 50 and 1,000 MPN/100 mL which were not consistent with a log normal distribution.

Statistics which rely on normal distributions may produce false positive measures of significance for the beach bacteria populations. Many single beach samples assembled through weekly sampling over 4 summers did not have sufficiently large populations to allow statistical assessment with such tests. For example, an attempt to compare Surfrider and Manhattan (40th Street) beaches during the summer of 2007 was not successful because of the distribution of the measures for Manhattan Beach (9 measures below 10 MPN/100 mL, one of 24,000 MPN/100mL and 5 of 10 MPN/100mL). The resulting sample distribution was not normally distributed nor was the natural log of the sample distribution normally distributed. A comparison of the data with the larger sample at Surfrider Beach varied with the interval to which the statistical test was applied.

Where data sets are large, normal distributions can be created through repeated sampling. However, the largest data sets also had very large measurements and many small measurements, suggesting that populations were not the result of sample bias. As an example, annual populations for all sewered and septic beaches which had high correlation coefficients for large and small intervals, but not for the interval between 50 and 1,000 MPN/100 mL.

If normality was assumed and Student's t-tests and Correlation Coefficient were applied, the results were repeatedly inconsistent. Some data sets which Student's t-test showed to have intervals from different populations were also found to have high Correlation Coefficients. Where a correlation was suspected and the data sets were plotted, the typical result was that a single very high or numerous very low values produced a large correlation coefficient (R^2) erroneously indicating that the correlation is good. Where the sample sets were distinct, did not correlate, and were suspected to be samples from different populations, the Student t-test (p) or the Student's t-test of the natural log (ln p) were measured. Small measures of p or ln p indicated that some populations were distinct with values above .05 considered significant (less than 1 chance in 20) .The typical result was that a Student t-test finding that the populations to be distinct was highly dependent on the size of the sample (and the number of values below 25 MPN/100mL) or the presence of a few measures above 1000 MPN/100 mL.

The statistic package Minitab was used to apply the Chi-square test. When the chi square correlation was made on truncated populations of all beaches with some values below 10 MPN/100 ML removed, the results (p<.05) indicated that septic and sewered beaches did not belong to the same population. However, the removal of about half of the population was of concern.

Non parametric statistical tools were applied to the same data sets. When all septic and sewered beaches for the year 2005 - 2008 were contrasted using the non-parametric Quartile Hypothesis Test, the Wilcoxon-Mann-Whitney (WMW)Test and Gehan Test from EPA's ProUCL statistical program, the Quartile Test results recommend using the WMW Test. However, the WMW Test is only applicable for data set with less than 40% non-detect level of 10 MPN/100mL. Therefore, the Gehan Test is the most appropriate Test for this study. The Gehan test looks at all intervals and emphasizes the mean/median interval. The results are summarized in Tables 1 through 4.

The Null Hypothesis is termed "Septic Beach Mean/Median Less Than or Equal to Sewer Beach Mean/Median;" and the Alternative Hypothesis is "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median" using Gehan Form 1 Test.

The result of the Gehan Test for 2005, 2006 and 2008 shows that the Null Hypothesis is rejected by a low P-value with an alpha value of 0.05 (a confidence level of 95%) , which rejects the Null Hypothesis and supports the Alternative Hypothesis "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median". The 2007 data is not consistent with the results of 2005, 2006, and 2008 due to low groundwater discharge to beaches after dry winter. The same results were also obtained with an alpha value of 0.01 (a confidence level of 99%) that enterococcus concentration at septic beaches is higher than concentration at sewered beaches statistically.

Table 1 - 2005 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options		
From File	WorkSheet.wst	
Full Precision	OFF	
Confidence Coefficient	95%	
Substantial Difference	0	
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)	
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median	

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	358	754
Number of Non-Detect Data	113	482
Number of Detect Data	245	272
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	31.56%	63.93%
Minimum Detected	20	20
Maximum Detected	9208	4200
Mean of Detected Data	261.7	368.9
Median of Detected Data	87	99
SD of Detected Data	661.3	591.3

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	9.461
Critical z (0.95)	1.645
P-Value	1.52E-21

Conclusion with Alpha = 0.05
Reject H0, Conclude Site > Background
P-Value < alpha (0.05)

D R A F T J U L Y 3 1 2 0 0 9

Table 2 - 2006 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	685	1377
Number of Non-Detect Data	293	921
Number of Detect Data	392	456
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	42.77%	66.88%
Minimum Detected	20	20
Maximum Detected	24192	48010
Mean of Detected Data	324.9	532.3
Median of Detected Data	86.5	42
SD of Detected Data	1320	2701

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test

Value	11.74
Critical z (0.95)	1.645
P-Value	4.17E-32

Conclusion with Alpha = 0.05
Reject H0, Conclude Site > Background
P-Value < alpha (0.05)

DRAFT JULY 31 2009

Table 3 - 2007 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	731	1364
Number of Non-Detect Data	574	1023
Number of Detect Data	157	341
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	78.52%	75.00%
Minimum Detected	10	20
Maximum Detected	2000	24192
Mean of Detected Data	127.5	260
Median of Detected Data	52	41
SD of Detected Data	281	1713

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	-1.226
Critical z (0.95)	1.645
P-Value	0.89

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site <= Background
P-Value >= alpha (0.05)

Table 4 - 2008 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	734	1315
Number of Non-Detect Data	514	979
Number of Detect Data	220	336
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	70.03%	74.45%
Minimum Detected	20	20
Maximum Detected	2000	2000
Mean of Detected Data	146.8	90.55
Median of Detected Data	53	31
SD of Detected Data	290.3	226.3

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	3.45
Critical z (0.95)	1.645
P-Value	2.81E-04

Conclusion with Alpha = 0.05
Reject H0, Conclude Site > Background
P-Value < alpha (0.05)

An additional measurement of significance using the Gehan test can be achieved by adding an investigation value (i.e. enterococcus concentration) to the mean/median before assessing the Null hypothesis to demonstrate the magnitude of difference using Gehan Form 2 Test. The larger this value, called substantial difference, S, the greater the difference between the populations, i.e., the greater an S, the greater an enterococcus concentration for septic beaches versus sewered beaches. Definitions from EPA's ProUCl program are detailed follow.

> Δ (delta): The true difference between the mean concentration of X in one sample and the mean of X in a second sample. Delta is an unknown parameter which describes the true state of nature. Hypotheses about its value are evaluated using statistical hypothesis tests. In principle, we can select any specific value for Δ and then test if the observed difference is as large as Δ or not with a given confidence and power.
>
> S (substantial difference): A difference in mean concentrations that is sufficiently large to warrant additional interest based on health or ecological information. S is the investigation level. If Δ exceeds S, the difference in concentrations is judged to be sufficiently large to be of concern, for the purpose of the analysis. A hypothesis test uses measurements from the site and from background to determine if Δ exceeds S.

In the study cases, the S value was calculated to determine the significance of the contrast between sewered and septic beaches for the summers of 2005, 2006, 2007 and 2008. The resulting S values show that septic beaches were most distinct from sewered beaches in 2005 after wet winter and not distinct in 2007 after dry winter. A substantial difference exists between septic and sewered beaches for every year except 2007.

Year	2005	2006	2007	2008
S value MPN/100 mL	108	89	0	21

The Gehan calculation with S factor calculation for the 2005 - 2008 are shown in Tables 5 - 8.

D R A F T J U L Y 3 1 2 0 0 9

Table 5 – 2005 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	108
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	358	754
Number of Non-Detect Data	113	482
Number of Detect Data	245	272
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	31.56%	63.93%
Minimum Detected	20	20
Maximum Detected	9208	4200
Mean of Detected Data	261.7	368.9
Median of Detected Data	87	99
SD of Detected Data	661.3	591.3

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 108

Gehan z Test Value	-1.631
Critical z (0.95)	-1.645
P-Value	0.0514

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 108.00
P-Value >= alpha (0.05)

Table 6 – 2006 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	89
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches

Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	685	1377
Number of Non-Detect Data	293	921
Number of Detect Data	392	456
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	42.77%	66.88%
Minimum Detected	20	20
Maximum Detected	24192	48010
Mean of Detected Data	324.9	532.3
Median of Detected Data	86.5	42
SD of Detected Data	1320	2701

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 89

Gehan z Test Value	-1.353
Critical z (0.95)	-1.645
P-Value	0.088

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Site >= Background + 89.00

P-Value >= alpha (0.05)

Table 7 – 2007 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	731	1364
Number of Non-Detect Data	574	1023
Number of Detect Data	157	341
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	78.52%	75.00%
Minimum Detected	10	20
Maximum Detected	2000	24192
Mean of Detected Data	127.5	260
Median of Detected Data	52	41
SD of Detected Data	281	1713

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 0

Gehan z Test Value	-1.226
Critical z (0.95)	-1.645
P-Value	0.11

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 0.00
P-Value >= alpha (0.05)

Table 8 – 2008 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	21
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches

Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	734	1315
Number of Non-Detect Data	514	979
Number of Detect Data	220	336
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	70.03%	74.45%
Minimum Detected	20	20
Maximum Detected	2000	2000
Mean of Detected Data	146.8	90.55
Median of Detected Data	53	31
SD of Detected Data	290.3	226.3

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 21

Gehan z Test Value	-0.305
Critical z (0.95)	-1.645
P-Value	0.38

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Site >= Background + 21.00

P-Value >= alpha (0.05)

ATTACHEMENT 3-2: REFERENCES

Ambrose, Richard. May 14, 2008. Ecological Goals. Malibu Legacy Park Project prepared by Richard F. Ambrose in association with RMC Water and Environment

Allen, L.A., Brooks, E., Williams, & I.L. November 1949. Effect of Treatment at the Sewage Works on the Numbers and Types of Bacteria in Sewage. Prepared for The Journal of Hygiene by L.A. Allen, E. Brooks, & I.L. Williams.

Azadpour-Keeley, A., Faulkner, B.R., & Chen, J.S. April 2003. Movement and Longevity of Viruses in the Subsurface. Prepared for United States Environment Protection Agency by A. Azadpour-Keeley, B.R. Faulkner, and J.S Chen

Bales, R.C., Gerba, C.P., Grondin, G.H., & Jensen, S.L. 1989. Bacteriophage Transport in Sandy Soil and Fractured Tuff. Prepared for Applied and Environmental Microbiology by R.C. Bales, C.P. Gerba, G.H. Grondin, & S.L. Jensen.

Bing Yen & Associates, Inc. January 5, 2001. Report of Malibu Civic Center Groundwater Evaluation. Prepared for City of Malibu by Bing Yen & Associates, Camarillo CA.

Bloch, A.B., Stramer, S.L., Smith, D., Margolis, H.S., Fields, H.A., McKinley, T.W. Gerba, C.P., Maynard, J.E., & Sikes, R.K. April 1990. Recovery of Hepatitis A Virus from Water Supply Responsible for a Common Source Outbreak of Hepatitis A. Prepared for American Journal of Public Health by A.B. Bloch, S.L. Stramer, D. Smith, H.S. Margolis, H.A. Fields, T.W. McKinley, C.P, Gerba, J.E. Maynard, & R.K. Sikes.

Boehm, A.B., Shellenbarger, G.G., & Paytan, A. 2004. Groundwater Discharge: Potential Association with Fecal Indicator Bacteria in the Surf Zone. Prepared for Environmental Science & Technology by A.B Boehm, G.G. Shellenbarger, & A. Paytan.

Borchardt, M.A., Bertz, P.D., Spencer, S.K.,& Battigelli, D.A. 2003. Incidence of Enteric Viruses in Groundwater from Household Wells in Wisconsin. Prepared for Applied and Environmental Microbiology by M.A. Borchardt, P.D. Bertz, S.K. Spencer, & D.A. Battigelli.

Borchardt, M.A., Chyou, P.H., DeVries, E.O., & Belongia, E.A. May 2003. Septic System Density and Infectious Diarrhea in a Defined Population of Children. Prepared for Environmental Health Perspectives by M.A, Borchardt, P.H. Chyou, E.O. DeVries,& E.A. Belongia.

Cabelli, V.J. August 1983. Health Effects Criteria for Marine Recreational Waters. Prepared for Health Effect Research Laboratory Office of Research and Development by V.J. Cabelli.

CDM. August 10, 2006. Technical Memorandum Task 10, TMDL Implementation Analysis.

CDM. February 27, 2007. Integrated Total Maximum Daily Load Implementation Plan for the Malibu Creek Watershed. Prepared for Los Angeles County Department of Public Works by CDM, Irvine CA.

Chu, A.K., & Sanders, B.F. August 2008. Data Requirements for Load Estimation in Well-Mixed Tidal Channels. Prepared for Journal of Environmental Engineering by A.K. Chu, & B.F Sanders.

City of Malibu. November 5, 2002. Ordinance No. 242. City Council of the City of Malibu.

City of Marco Island. City of Marco Island Position Paper Septic Tank Replacement Program. Prepared by the City of Malibu for the City of Malibu.

Crawford, Multari & Clark Associates. July 1997. Draft, City of Malibu, Civic Center Specific Plan. Prepared for City of Malibu by Crawford, Multari & Clark Associates, San Luis Obispo CA.

Cuyk, S.V., Siergrist, R.L., Lowe, K., & Harvey, R.W. 2004. Vadose Zone Processes and Chemical Transport. Prepared for Journal of Environmental Quality by S.V Cuyk, R.L. Siergrist, K. Lowe, & R.W. Harvey.

De Sieyes, N.R., Yamahara, K.M., Layton, B.A., Joyce, E.H., & Boehm, A.B. 2008. Submarine Discharge of Nutrient-Enriched Fresh Groundwater at Stinson Beach, California is enhanced during Neap Tides. Prepared for Limnol Oceanography by N.R. de Sieyes, K.M. Yamahara, B.A. Layton, E.H. Joyce, & A.B. Boehm.

Ensitu Engineering Inc. June 30, 2008. Advanced On-site Wastewater Treatment System Design, California Department of Health Services Engineering Report. Prepared for Malibu Lumber by Ensitu Engineering Inc, Morro Bay CA.

Ensitu Engineering Inc. August 13, 2008. Malibu Lumber Wastewater Flow Calculations Commercial Development without Restaurant Use. Letter addressed to Brett Thornton, prepared by Ensitu Engineering, Morro Bay CA.

Ensitu Engineering Inc. 2008. Advanced On-site Wastewater Treatment System Design, City of Malibu Engineering Report. Prepared for Malibu Lumber by Ensitu Engineering Inc., Morro Bay CA.

Gold, M.A. 1994. What are the health risks of swimming in the Santa Monica Bay?: An examination of the issues surrounding the public health debate. Prepared for University of California, Los Angeles by M.A. Gold.

Goyal, S.M., & Gerba, C.P. August 1979. Comparative Adsorption of Human Enteroviruses, Simian Rotavirus, and Select Bacteriophages to Soils. Prepared for Applied and Environmental Microbiology by S.M. Goyal, & C.P. Gerba.

Gronewold, A.D.,& Wolpert, R.L. April 7, 2008. Modeling the Relationship between Most Probable Number (MPN) and Colony – Forming Unit (CFU) Estimates of Fecal Coliform Concentration. Elsevier.

Ground Water Monitoring and Assessment Program. May 1999. Effect of Septic Systems on Ground Water Quality – Baxter, Minnesota. Prepared for Ground Water Monitoring and Assessment Program by Ground Water Monitoring and Assessment Program

James, Kirsten. November 19, 2008. Comments on Tentative Waste Discharge Requirements, Water Reclamation Requirements and Monitoring and Reporting Program for Malibu Lumber. Heal The Bay, Santa Monica CA.

Jones & Stokes. 2008. Malibu Legacy Park Project, Draft Environmental Impact Report. Prepared for City of Malibu by Jones & Stokes, Los Angeles CA.

REGIONAL BOARD. 1972. Resolution No. 72-4, Policy Statement Relative to Sewage Disposal in the Malibu Area. California Regional Water Quality Control Board, Los Angeles Region.

LARWCB. December 14, 1998. Resolution No. 98-023 Malibu Creek Watershed. California Regional Water Quality Control Board, Los Angeles Region.

REGIONAL BOARD. 1990. Regional Water Quality Control Board's Interim Policy on the Use of Septic Tanks. California Regional Water Quality Control Board, Los Angeles Region.

REGIONAL BOARD. 2002. Santa Monica Bay Beaches Wet Weather Bacteria TMDL, Item #5 Regional Board Workshop, June 27, 2002. California Regional Water Quality Control Board, Los Angeles Region.

REGIONAL BOARD. 2004b. Total Maximum Daily Loads for Bacteria, Malibu Creek Watershed. California Regional Water Quality Control Board, Los Angeles Region.

REGIONAL BOARD. 2008. 520th Regular Board Meeting, Item 16, Consideration of Termination of Memorandum of Understanding for On-site Wastewater Treatment Systems for the City of Malibu. California Water Quality Control Board, Los Angeles Region.

REGIONAL BOARD. 2008b. 521st Regular Board Meeting, Item 18, Revised Order, Waste Discharge Requirements/Water Reclamation Requirements and Monitoring and Reporting Program for City of Malibu's Malibu Lumber at City of Santa Monica's Legacy Park. California Regional Water Quality Control Board, Los Angeles Region.

Lucero, Gene. 2008. Submittal of Comments to Tentative Waste Discharge Requirements and Water Reclamation Requirements for Malibu Lumber LLC. Latham & Watkins, LLP.

National Center for Environment Research. 2003. Final Report: Fate for Pathogens in Storm Water Runoff. Prepared for National Center for Environment Research by National Center for Environment Research.

Nicosia, L.A., Rose, J.B., Stark, L., & Stewart, M.T. 2001. Ground Water Quality. Prepared for Journal of Environment Quality by L.A Nicosia, J.B Rose, L. Stark, and M.T. Stewart.

Noble, R.T, & Fuhrman, J.A. October 25, 1996. Virus Decay and Its Causes in Coastal Waters. Prepared for Applied and Environmental Microbiology by R.T. Noble, & J.A. Fuhrman.

Office of Water. October 2006. Occurrence and Monitoring Document for the Final Ground Water Rule. Prepared for Office of Water by the Office of Water.

Peter Warshall & Associates and Philip Williams & Associates. 1992. Malibu Wastewater Management Study, A Human Ecology of the New City. Prepared for City of Malibu by Philip Williams and Associates, San Francisco CA and Peter Warshall & Associates, Tucson AZ.

Pradhan, S., Hoover, M.T., Clark, G.H., Gumpertz, M., Wollum, A.G., Cobb, C., & Strock, J. February 2008. Septic Tank Additive Impacts on Microbial Populations. Prepared for Journal of Environmental Health by S. Pradhan, M.T. Hoover, G.H. Clark, M. Gumpertz, A.G. Wollum, C. Cobb, & J. Strock

Questa Engineering Corporation. July 7, 2003. Preliminary Conceptual Plan for Wastewater Reclamation in the Civic Center Area, Malibu, California. Prepared for City of Malibu by Questa Engineering, Santa Barbara CA.

RMC Water and Environment. August 15, 2008. Irrigation of Legacy Park with Treated Effluent from Lumber Yard Development. Technical Memorandum prepared by RMC Water and Environment.

RMC Water and Environment. May 14, 2008. Summary of Stormwater Management and Water Quality Improvements for Lower Malibu Creek and Lagoon. Prepared by RMC Water and Environment for City of Malibu, Legacy Park.

Rong, Y. November 3, 1997. Pitfalls in Statistics for Environmental Sampling Evaluation. Prepared for Environmental Geosciences by Yue Rong.

Santa Monica Bay Restoration Project. 1999. Malibu Creek Watershed Restoration Activities Draft. Malibu Creek Watershed Executive Advisory Council.

Santa Monica Bay Restoration Project. January 2001. Improving Septic System Management in the Santa Monica Bay Watershed. Santa Monica Bay Restoration Project, Septic System Task Force.

Schaub, S.A., & Sorber, C.A. May 1977. Virus and Bacteria Removal from Wastewater by Rapid Infiltration Through Soil. Prepared for Applied and Environmental Microbiology by S.A. Schaub, & C.A. Sorber.

Schijven, J.F. & Hassanizadeh, S.M. 2002. Virus Removal by Soil Passage at Field Scale and Groundwater Protection of Sandy Aquifers. Prepared for Water Science and Technology by J.F Schijven & S.M Hassanizadeh .

Stone Environmental, Inc. 2004. Final Report- Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu CA. Prepared for Santa Monica Bay Restoration Commission by Stone Environmental, Montpelier VT.

Stone Environmental, Inc. April 9, 2004. IWIMS Design Document, City of Malibu Clean Beaches Initiative. Prepared for S. Groner Associates, Inc by Stone Environmental, Montpelier VT.

Stone Environmental, Inc. May 6, 2004. IWIMS Design Document, City of Malibu Clean Beaches Initiative. Prepared for S. Groner Associates, Inc by Stone Environmental, Montpelier VT.

Stramer, S.L., & Cliver, D.O. 1984. Septage Treatments to Reduce the Numbers of Bacteria and Polioviruses. Prepared for Applied and Environmental Microbiology by S.L. Stramer,& D.O. Cliver.

Tiefenthaler, L.L, Stein, E.D., & Lyon, G.S. January 2008. Fecal Indicator Bacteria Levels During Dry Weather form Southern California Reference Streams. Prepared for Southern California Coastal Water Research Project by L.L. Tiefenthaler, E.D. Stein, & G.S. Lyon.

Tim, Heather. November 1994. Review of Monitoring and Response Protocol for the Malibu Creek Watershed. Santa Monica Bay Restoration Project.

Thorsen, Jim. 2008. Letter in Response to the Los Angeles Regional Water Quality Control Board's Letter Regarding Notification of Incomplete Application for Waste Discharge Requirements for Malibu Lumber. City of Malibu, CA.

United States Environmental Protection Agency. January 2001. Linkage between Water Quality Targets and Pollutant Sources. Prepared for United States Environmental Protection Agency by United States Protection Agency.

United States Environmental Protection Agency. August 2002. Predicting Attenuation of Viruses During Percolation in Soils. Prepared for United States Environmental Protection Agency by United States Protection Agency.

University of California, Los Angeles. May 200. Lower Malibu Creek and Lagoon Resource Enhancement and Management. Final Report to the California State Coastal Conservancy by UCLA.

URS Greiner Woodward Clyde. 1999. Final Report, Study of Potential Water Quality Impacts on Malibu Creek and Lagoon from On-site Septic Systems. Prepared for City of Malibu by URS Greiner Woodward Clyde, Santa Ana CA.

US Environmental Protection Agency. January 10, 2003. Total Maximum Daily Loads for Nutrient, Malibu Creek Watershed, Public Review Draft. US Environmental Protection Agency, Region 9.

Van Beveren & Butelo Inc. 2008. Supporting Geology/Soils Report Proposed Legacy Park Discharge Area. Prepared for Malibu Lumber, LLC by Van Beveren & Butelo Inc

Van Beveren & Butelo Inc. February 20, 2008. Supporting Geology/Soils Report Proposed Legacy Park Discharge Area. Prepared by Van Beveren & Butelo Inc for Malibu Lumber LLC.

Van Beveren & Butelo Inc. June 27, 2008. Response to Comments by the City of Malibu Proposed Legacy Park Discharge Area. Prepared by Van Beveren & Butelo Inc for Malibu Lumber LLC.

Van Beveren & Butelo Inc. August 11, 2008. Response to Comments by the City of Malibu Proposed Legacy Park Discharge Area. Prepared by Van Beveren & Butelo Inc for Malibu Lumber LLC.

Van Beveren & Butelo Inc. October 13, 2008. Response to Comments by the City of Malibu Proposed Legacy Park Discharge Area. Prepared by Van Beveren & Butelo Inc for Malibu Lumber LLC.

Vaughn, J.M., Landry E.F., Baranosky, L.J., Beckwith, C.A., Dahl, M.C., & Delihas, N.C. July 1978. Survey of Human Virus Occurrence in Wastewater-Recharged Groundwater on Long Island. Prepared for Applied and Environmental Microbiology by J.M. Vaughn, E.F. Landry, L.J. Baranosky, C.A. Beckwith, M.C. Dahl, & N.C. Delihas.

Viergutz, Richard, 2006, Discharge of Sewage-Polluted Groundwater into Malibu Creek and Lagoon Resulting from Groundwater Surface Interactions: MS Thesis, California State University, Los Angeles

Yates, M.V., Gerba, C.P., & Kelley, L.M. April 1985. Virus Persistence in Groundwater. Prepared for Applied and Environmental Microbiology by M.V. Yates, C.P. Gerba, & L.M. Kelley.

Yates, M.V., Yates, S.R., Warrick, A.W., & Gerba C.P. September 1986. Use of Geostatistics to Predict Virus Decay Rates for Determination of Septic Tank Setback Distances. Prepared for Applied and Environmental Microbiology by M.V. Yates, S.R. Yates, A.W. Warrick, and C.P. Gerba.

Yamahara, K.M., Layton, B.A., Santoro, A.E., & Boehm, A.B. 2007. Beach Sands along the California Coast are Diffuse Sources of Fecal Bacteria to Coastal Waters. Prepared for Environmental Sciences & Technology by K.M. Yamahara, B.A. Layton, A.E Santoro, & A.B. Boehm.

Yamahara, K.M., Walters, S.P., & Boehm, A.B. January 6, 2009. Growth of Enterococci in Unaltered, Unseeded Beach Sands Subjected to Tidal Wetting. Prepared for Applied and Environmental Microbiology by K.M. Yamahara, S.P Walters, & A.B. Boehm.